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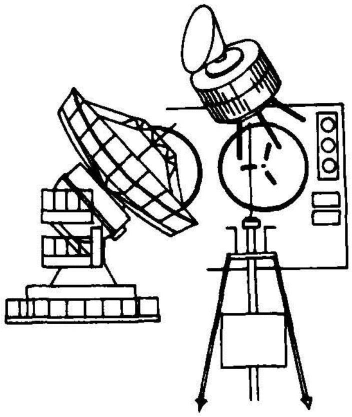
Concepts For Data Collections In The Arctic

Final Technical Report

May 1972



Prepared by

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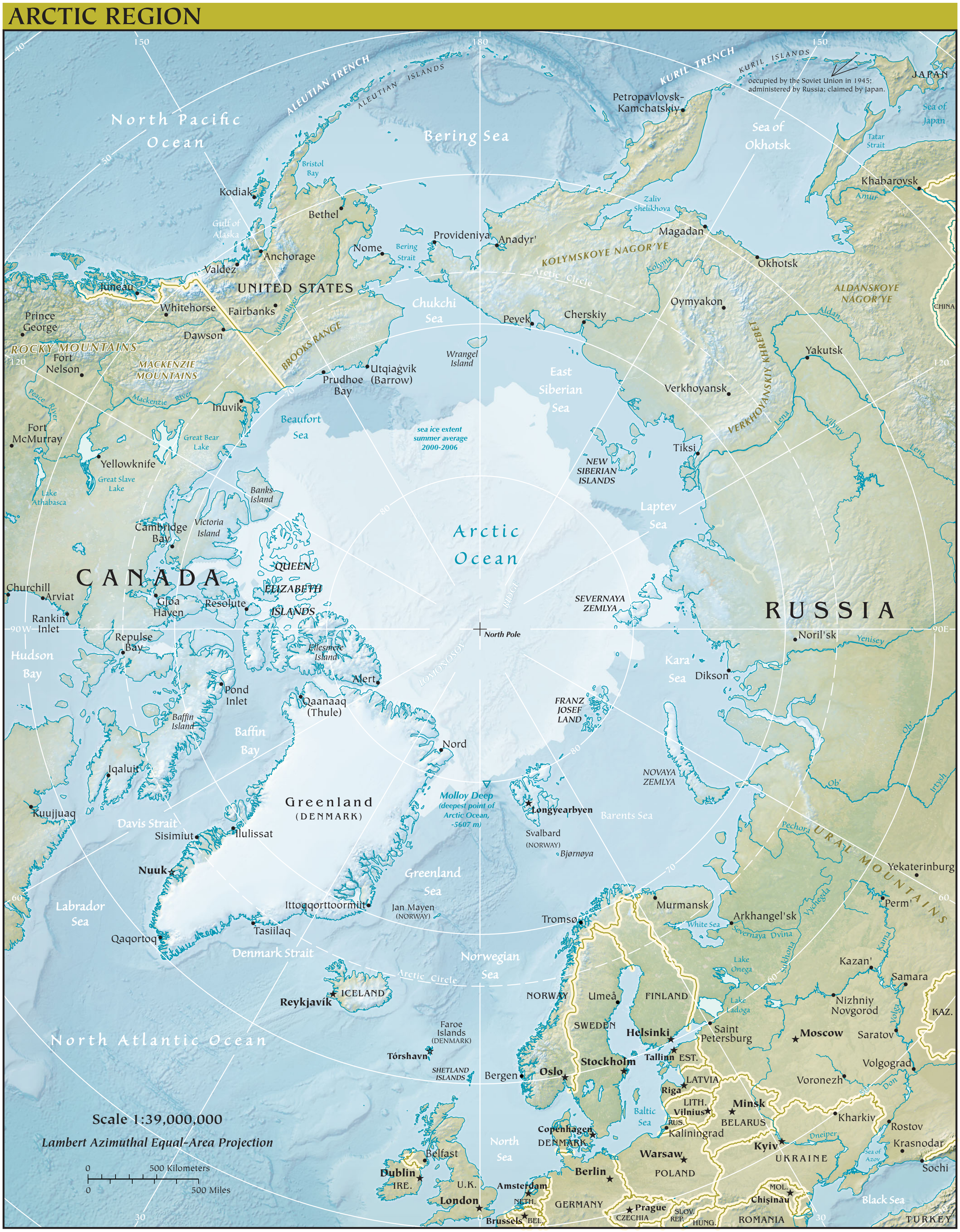
ARCTIC REGION



SECTION III

ARCTIC ENVIRONMENT

In this report, the Arctic Basin is defined as that area surrounding the North Pole. Included in this area are the Arctic Ocean and its seas, the many water passages that connect the Arctic Ocean with the Atlantic and Pacific oceans, and adjoining land areas with continuous permafrost. (See Figure 1.)

The environment presents the greatest challenges to scientists who conduct research in the Arctic Basin. The following discussion relates some environmental factors that profoundly affect both scientists and the equipment they use to conduct research.

Sea Ice

Sea ice rarely forms in the open ocean below 60°N, but it may drift far south of this latitude. Between 60°N and 75°N, the occurrence of sea ice is a seasonal matter, and there is usually a period of the year when the water is ice free. Above 75°N, there is a more or less permanent ice cover. (See Figures 2 and 3.) Even in winter, however, the Arctic Ocean is never totally ice covered. A recent estimate, based on infrared temperature measurements, is that as much as 10 percent of the Arctic Ocean is either open water or thin ice over refrozen leads.

There is little accurate data on the height and frequency of pressure ridges in the Arctic Ocean, but heights of 26 to 33 feet are occasionally seen and heights of 13 to 16 feet above the average ice surface are common. To date, it has not been possible to determine a roughness coefficient. The number of pressure ridges per mile may vary from 0 to 60 or more. Because of its density, uniform sea ice floats with 87 percent of its volume below sea level. When a pressure ridge is formed it tends to sag or slump because of the plasticity of ice.

From data obtained by the U.S. Navy's Project Birdseye and from the upward-beamed acoustic data obtained during the 1957 through 1962 under-ice cruises of submarines, the arctic pack ice has no consistent thickness. Constant fracturing, diverging, and compacting motions result in a spectrum of thicknesses ranging from a few inches to more than 15 feet. The data further indicate that the ridges and hummocks, whose drafts may average 40 feet in summer and 55 feet in winter, contribute significantly to the total ice volume. On rare occasions sea ice ridges may attain a thickness of 200 feet. The general movement of ice in the Arctic Ocean is shown in Figure 4.

Open Water Zones

Coastal configurations, especially geographic obstructions in the path of moving ice, profoundly affect sea ice distribution. The famous "North Water," which in midwinter occupies an area of 4,000 square miles and is recurrently

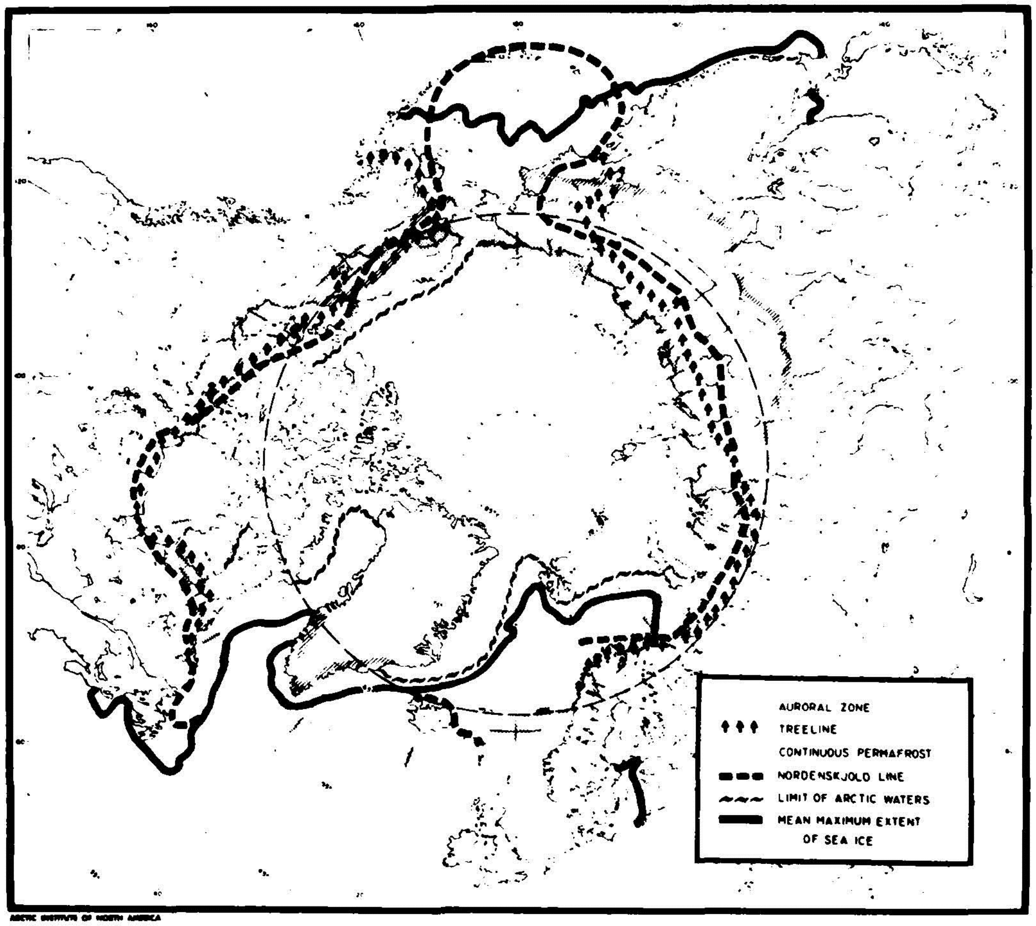


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Figure 1. SOME SIGNIFICANT BOUNDARIES IN THE ARCTIC REGION

found in northern Baffin Bay, has long been known by whalers as a prime example of the "centers of sea ice removal" that occur near coasts or coastal regions bordering the pack ice. Common smaller scale coastal phenomena of this type are flaw leads of navigable size between the shore fast ice and the moving pack ice. Both the flaw leads and the large-scale zones such as North Water may be open or covered with thin ice. They may also contain fragments of thicker drift ice commonly called "clutter." These phenomena are not completely understood but are believed to be caused mainly by coastal configurations, wind, and current-induced drift.

Wind

Surface winds over the Arctic Ocean average between 8 and 10 knots. The wind regimen of Alaska is to some extent monsoonal. In summer months, a thermal low develops over the interior of Alaska; in winter months, high pressures are prevalent. Surface winds vary with locale, but generally average from 4 to 5 knots.

The frequency of gales in Alaska also vary with locale. For example, Point Barrow on the Arctic Ocean coast averages 19 gales per year, whereas Fairbanks in the interior averages only 1 gale per year.

Temperature

A variety of climatic conditions is encountered in arctic regions. Areas adjacent to one another have widely differing climatic characteristics, depending on latitude, marine influence, and topography. Annual temperature curves show three well-defined types: maritime, coastal, and continental:

1. The Arctic Ocean has a flat temperature curve during June, July, and August with small deviations from the freezing point. The winter curve is also flat, temperatures remaining nearly constant around -29°F.

2. The coastal climate is nearly similar to the maritime climate. The year consists of a long, cold winter and a short, cool summer. The annual temperature curve has the same winter characteristics as that of the Arctic Ocean, but there is a seasonal maximum in July. The mean summer temperature, however, remains below 50°F.

3. The continental climate is characterized by pronounced winter minimums and summer maximums, where the annual range of mean temperature may be as much as 110°F.

In summer, the melting of snow and ice above latitude 75°N keeps the surface temperature close to the freezing point. The number of days with a maximum temperature slightly above the freezing point is about 40 days. Near the North Pole, positive temperatures are usually observed for 10 to 15 days in late July.

Warm inland air is often transported a considerable distance over the Arctic Ocean but, in passing over the ice-filled waters, it is cooled so effectively by contact with the ice that a sharp inversion is formed. Hence, the warm air current flows at some distance above the ground and has practically no influence on the surface temperature.

The relative humidity over ice has a maximum in midwinter (103 percent) and a minimum in June (95 percent), while the relative humidity over water has a maximum in August (96 percent) and a minimum in midwinter (73 percent). The pressure of the water vapor is small in midwinter (0.3 mb) and maximum in July and August (6 mb).

Visibility

Hoarfrost is formed when the relative humidity over ice is greater than 100 percent. The amount of hoarfrost deposition is greatest at around -20°F, while the probability of hoarfrost has a maximum at about -26°F. In July and August, there is relatively little hoarfrost since air temperatures usually are around the freezing point. Otherwise, the smallest amounts occur in April and the greatest amounts in September when the air is saturated with water from numerous open leads in the sea ice. Hoarfrost represents about 15 percent of the total annual precipitation.

Several types of fogs occur during various times of the year throughout the Arctic Basin. Water fogs form during warm months, mostly over pack ice. Steam fogs develop in winter when cold air contacts open leads in ice. Ice fogs occur when large quantities of water vapor are added to cold air. These usually are restricted to airports and inhabited areas. Radiation fogs occur in winter during temperature inversions. They are especially prevalent over the pack ice and river valleys where air movement is often sluggish.

The most serious threat of fogs is in aircraft operations, particularly since many airports are not equipped for instrument flying. Fortunately, most fogs in the Arctic are thin and shallow, and of short duration.

Visibility in the Arctic is a complex one due to the extreme clarity of the air. It is not uncommon to see dark mountains 80 miles distant. On the other hand, the lack of contrast, particularly where all surface objects are covered with new snow, results in the inability to distinguish objects close at hand. As the arctic atmosphere is fairly uncontaminated, the visibility will be reduced only, apart from fog, by precipitation or blowing snow.

Wind speeds of about 5 knots will cause unconsolidated snow to drift along the surface. At speeds of 10 to 15 knots, the snow is lifted into the air, and when it reaches a height of 6 feet the term blowing snow is used. Coastal stations around the Arctic Ocean may experience more than 100 days of blowing snow per year.

The frequent temperature inversions of the Arctic explain the many accounts of mirages. Objects that are known to be below the horizon sometimes become visible as mirages. Inversions may also interfere with the identification of landmarks through distortion, and make estimation of vertical distances more difficult.

Whiteout is a simple phenomenon with easily understood causes and only one direct effect: the loss of depth perception. This results in unexpected and sometimes disastrous consequences. The only recourse on the surface is to shuffle along at a slow pace; in the air, the only safe procedure is "instrument flying," making landing difficult, if not impossible, at many arctic airfields.

Most concern about whiteout is in relation to flying safety. Whiteout is generally a problem to the pilot in landing, taking off, and taxiing. Flying at altitudes less than 1,000 feet above the terrain, however, is particularly hazardous under these conditions.

Precipitation

Except for Greenland, precipitation is light in the Arctic. Continental areas have maximum precipitation in late summer, so a large part of the annual total falls as rain. Along the margins of the Arctic Ocean the winter accumulation of snow is, for the most part, less than 10 inches; the Siberian and Canadian arctic coasts receive as little as 5.5 inches per year (including rain and the water equivalent of snow). The annual precipitation over the Arctic Ocean is meager, about 5 inches. It is mainly in the form of snow and falls during autumn and late spring. Minimum precipitation occurs in winter.

Although the amount of precipitation along the arctic coasts is small, the ground remains saturated throughout the summer, for two reasons: (1) the ground is flat, so run-off is slight, if at all, and (2) permafrost prevents water seepage through the subsoil.

Over the central Arctic Ocean, the snow cover becomes established in late August. The thickness may be about 14 to 16 inches by late spring. Snow melting from solar radiation usually begins by the middle of June. Except in unusual years, the ice is usually snow free by the middle of July.

SECTION IV

RADIO PROPAGATION

Very low-frequency (VLF) communication systems are primarily for broadcasting over a large area with path lengths up to about 6,000 miles. These systems carry only 10 to 100 words a minute. Because of the high cost of such VLF installations, they are not used for point-to-point communications in the Arctic. Since VLF systems exist throughout the arctic region, however, they do provide a useful broadcast service as well as a means of navigation.

Arctic ionospheric conditions modify VLF propagation characteristics slightly. For most applications other than precise navigation, this effect is rather negligible.

Low-frequency (LF) systems are used for both broadcast and point-to-point communications, and also for navigation in arctic regions. The low conductivity of some of the land modifies considerably the design procedures for antenna installations as well as the overall system design. Although the low conductivity regions often present additional problems, efficient transmitting antenna systems are still feasible. LF systems have a low data rate (100 to 500 words a minute). Although the transmitting antenna installations can be large (330 to 1,300 feet high), the receiving antennas can be small (less than 3 feet high).

At low frequencies, the propagation mode involved is primarily the ground wave or a combination of ground and sky waves. The fields produced for ice cap paths are very highly attenuated compared with fields over sea water. In addition, when sky wave propagation is involved, the conductivity for a few wavelengths in the foreground of the antenna can become important. This factor must be very carefully considered in the design of any LF system in the Arctic. At present, there are installations where a relocation of several miles would increase the effective radiated power for the sky wave paths by 10 to 20 dB. Typical transmitter powers range from 10 to 50 kilowatts, with useful path lengths ranging from 150 to 1,500 miles.

Ionospheric disturbances that frequently interrupt normal high-frequency (HF) communications in the Arctic have little effect upon the low frequencies. In fact, in the lower portion of this band the field strength may actually be enhanced during such disturbed periods.

The medium-frequency (MF) portion of the frequency spectrum is of limited usefulness in the Arctic because of the rapid attenuation of the ground wave mode as well as the high attenuations on reflections from the ionosphere. The upper portion of the MF band is useful during undisturbed night conditions as well as for communications along paths that are primarily over sea water. The MF band has two advantages over VLF and LF bands: the transmitting antennas are smaller, and the atmospheric noise levels are lower. The ranges available, however, are also considerably smaller, but for some short paths, usually 60 miles or less, MF systems may be the most economical solution. There are some short-range mobile systems operating in this band. Other uses include navigation systems such as A-N beacons and LORAN.

At high frequencies (HF) it is possible to obtain good communications over long distances (up to several thousand miles) with much lower transmitter powers than at the lower frequencies. The antennas required are relatively small, about 6 to 65 feet long, and simple configurations are useful. For sea water paths, the ground wave propagation mode provides good communication for up to several hundred miles. Over poor arctic soil or ice caps, the useful range in some cases is less than 6 miles. The sky wave mode, useful in the region from 60 to 1,000 miles, makes use of ionospheric reflections from the E and F layers. In this frequency band, an appreciable amount of sky wave energy is absorbed as the rays traverse the D layer. Since this absorbing layer has to be traversed twice for each sky wave hop and the absorption for each traverse becomes quite high in polar regions, HF communication links are highly susceptible to blackouts caused by auroral and ionospheric disturbances. Since this type of attenuation decreases with increasing frequency, it is usually desirable to use as high a frequency as will effectively be reflected from the E or F layer under disturbed conditions.

The sky wave mode also suffers two additional disadvantages. First, multipath scattering, particularly that occurring during an aurora, can result in severe fading with rates roughly proportional to frequency. The rather large time delays can be so severe as to make voice signals unintelligible. Second, depending upon ionospheric conditions and the length of the path, the radio wave may penetrate the E and F layers completely instead of being reflected. This tends to limit operations to that part of the HF band below about 15 MHz.

The maximum usable frequency will depend on the time of day, the season, the terminal locations, and the phase of the sunspot cycle. Contrary to conditions at VLF, where the atmospheric noise levels are rather low, the antenna noise levels in the Arctic can be high primarily because of cosmic radio noise that has penetrated the ionosphere.

The rather simple installations required, the low radiated powers and appreciable bandwidth (typically several Hz), and the wide range of path lengths that can be employed make the HF system a fairly useful method of communication in the Arctic. The disadvantages include frequent communication failures that are due to excessive absorption, multipaths, or maximum usable frequency failure. The possible means of reducing these failures include: (1) decreasing the receiver bandwidth at the expense of the data rate, which sometimes causes frequency stability problems; (2) using vertical polarization, which would be significant, however, only for frequencies at or near 1 and 3 MHz; (3) careful selection of frequencies; (4) careful siting of antennas to permit high conductivity paths where possible for short ranges, or launching over a short section of high conductivity soil; (5) using receivers with low noise figures; and (6) SSB modulation for voice and data systems against multipath techniques.

The propagation of ionospheric scatter makes use of scattering by irregularities in the ionized D region. The effective forward scattering coefficient at very high frequencies (VHF) is quite low, and such systems require large directional antennas and powerful transmitters. For this reason, ionospheric forward scattering is not an effective communication system for small mobile groups or ships. Its advantages include long path lengths, roughly up to about 1,000 miles, and a number of data links. Because both absorption and scatter are critically dependent upon frequency, the optimum frequency range in the Arctic is fairly narrow, somewhere between 50 and 70 MHz. Because of the rather high cost and inflexibility of such systems, their use is quite limited.

VHF propagation may also involve the scattering of radio waves from meteor trails. In this technique, transmitters operate continuously on closely spaced frequencies at each end of the circuit until a trail of meteor ionization occurs with a position and orientation that permit a predetermined energy level to be exceeded at the receiving terminal. The receipt of such a signal is used as an indication that good propagation is available, and the message is immediately transmitted at high speed until the adjoining receiver shows that the propagation mode has faded below some preset level. This intermittent communication system has the advantage of lower radiated power requirements than the standard ionospheric forward scatter system. Also, because of the character of the propagation, it is relatively private. Path lengths of up to 1,200 miles may be used. It has been found that, like the VHF ionospheric forward scatter mode, meteor burst communication links are much less affected by high-latitude ionospheric disturbances than are HF communication links.

Both types of VHF ionospheric scatter can be disturbed by major polar cap absorption caused by the widespread bombardment of the polar ionosphere by solar protons. Such events have occurred several times each year during sunspot maximums and are likely to cause severe attenuation or even complete failure of the link during daylight hours for periods of 2 to 4 days. The defect of meteor burst communication systems is the intermittence of the propagation path. The delay time depends upon the sensitivity of the system, which is a function of the operating frequency, the radiated power, the bandwidth, and the sensitivity of the receiving system. Under some circumstances, when instantaneous communication is not required, meteor burst communication is acceptable.

Another method of VHF propagation is scatter from auroral ionization. This form of scatter decreases rapidly in intensity with increasing frequency. Even so, the high frequency of 3,000 MHz has been observed. As a communication technique its disadvantages include a rapid fade rate and intermittent and unpredictable propagation. Under certain conditions in the lower portion of the VHF band (30 to 60 MHz), strong auroral scatter signals can be expected during ionospheric disturbances, and this propagation mode can then serve as an HF backup circuit.

Any such link must take into account the pronounced directional sensitivity and limited height of the auroral ionization. This ionization tends to act like a metallic mirror inclined parallel to the magnetic field lines and is most common at heights of about 60 miles. In general, east-west propagation in the Arctic would be via auroral forms to the north of the midpoint. North-south auroral scatter propagation would involve ionization several hundred miles to the north of the northernmost station. In other words, for north-south auroral scatter modes, both antennas should be directed northward at low angles of elevation toward a common scattering column in which the line of sight is approximately perpendicular to the earth's magnetic field lines.

Ultrahigh frequencies (UHF) are useful for short-range, line-of-sight systems where the antennas are small and the powers low enough that mobile or hand-carried equipment can be employed. For conditions where the line of sight does not obtain between the transmitter and receiver, it is possible to use some type of relay mode, such as passive reflectors, mountain diffraction, airborne relays, and satellite relays. Most of these modes, with the possible exception of mountain diffraction, have wide bandwidth capabilities. At the greater ranges directional antennas are usually employed, but for moderate gains their size is not great.

Still another useful type of propagation mode in this frequency range is tropospheric scatter, which has found wide application in the Arctic. When properly engineered, such systems are reliable, are not subject to failure because of ionospheric disturbances, and may have an unusually wide bandwidth capacity (up to a few megahertz) depending upon the system parameters. The major disadvantage is the high cost of the large antennas and powerful transmitters needed to overcome the high losses of the troposcattering mode.

Although it is possible to use the superhigh frequencies (SHF) for short-range, direct, or line-of-sight communications, it is usually more economical to use VHF or UFH systems. The present-day application for SHF is in satellite relays, although some of the satellite systems are also active in the UHF region. Future use of SHF may expand, however, because it does offer the broadest bandwidth to accommodate proliferating needs. Radio circuits in the Arctic are assessed in Table I.

References

1. Sater, J. E., A. G. Ronhovde, and L. C. Van Allen. Arctic Environment and Resources. Arctic Institute of North America, November 1971.

2. Sater, J. E. The Arctic Basin (Revised Edition). Arctic Institute of North America, August 1969.

3. Landmark, B. (Ed). Arctic Communications. Advisory Group (Aerospace R&D), NATO, 1964.

6. GENERATORS

6.1 General

6.1.1 Output capacities of generators in current Army inventory range from 0.4 to 15.0 kw DC for engine-driven generators. These generators are designed to operate in ambient temperature as low as -54°C (-65°F). When the ambient temperature is below -32°C (-25°F), however, the batteries and the engine driving the generator need to be preheated in order to start the engine. Winterization equipment varies in composition and function depending on the type of generator it is used with. Preheating can be accomplished with integrally mounted winterization heating equipment and/or a portable auxiliary winterization kit.

6.1.2 An additional function of winterization kits on generator sets is to provide as much protection for the equipment as is practical both during operation and shutdown. When operating in cold environments (below -18°C (0°F)) canvas covers or other protective shelters around the equipment are commonly employed. Whereas some generators are supplied with canvas covers, in other cases the generators are protected, when not in use, by expedient protective covers drawn from local supplies. This permits easier servicing and better performance of the equipment. For correct arctic winter operation and maintenance of the generator set, refer to the appropriate TM for the proper use of thermostats, shutters, and cooling shrouds.

6.2 Integrally-Mounted Winterization Equipment

6.2.1 Engine and Battery Heaters: Both fuel-burning and electrical resistance type heaters are employed to provide heat to engine oil, intake manifold, engine coolant, batteries, and fuel. Further technical information pertaining to the application of heat to cold-soaked internal combustion engines can be found at para 3.1.6. In addition to the electrically ignited fuel-burning heaters similar to those applied on tank/automotive equipment, blowtorches and electrical resistance type heaters are also used.

a. Electrically ignited fuel-burning heaters. Detailed descriptions of these types of heaters can be found at para 3.1.6. They may be of either the coolant or hot air heating type which through the use of ducts and/or coolant hoses apply heat to critical components of the engine, batteries, and electrical system of the generator. Fuel for these heaters is usually taken from the generator fuel supply be means of a fuel pump and line installed specifically for the heater. Thermostats are frequently designed into the systems to regulate the output of the heater within acceptable limits.

b. Electrical resistance heaters. Engine heaters of this type may consist simply of a coil which is mounted directly in the oil pump (referred to as an engine base oil heater in TM 5-6115-300-15[15], or contains a similar coil encased in a tank, which in turn is used to heat the coolant of the engine and circulate it by thermosyphon action. Batteries may be heated by electrical resistance "blankets" or "plates" which are mounted around or under the battery, respectively.

c. Manifold heaters. Intake manifold heaters of either the fuel-burning type (refer to paragraph 3.1.8) or electrical resistance type may come installed. As with tank/automotive engines, the manifold heaters are frequently part of the basic generator, not necessarily part of the arctic adaptation kit.

6.2.2 Ether injectors: Pressurized ether injection systems are used on some diesel engine-driven generators and are designed for temperatures below 4°C (40°F). A metered shot of ether is injected into the engine air intake system to aid combustion through the high volatility of the ether. Excess ether, or the use of ether in warm engines, can damage the engine; therefore, great care must be exercised in its use.

6.2.3 Protective Shrouds, Doors, and Covers: Generators are commonly equipped with these devices, ranging from canvas covers, tailored to small air-cooled generators, to automatically controlled radiator shutters for larger liquid-cooled generators. These devices are used to protect the equipment from chilling winds, snow, and low temperature, and to retain the unit at proper operating temperature. An exhaust manifold heat exchanger and shutter in the air cleaner is used to provide preheated air to the carburetor during low temperature operation (below -4°C (25°F)) of some units.

6.3 External Winterization Equipment: These items are used as prescribed by the appropriate TM. Any heater (e.g., Heater, Duct, Type, Portable, 400,000 BTU), slave kit (e.g., M40 Slave Kit), battery charging device, or enclosure used in conjunction with the generator, constitutes an external winterization kit. Canvas or wooden enclosures are commonly locally fabricated to provide necessary protection for generators operating for long periods in the arctic.

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[15] Footnote number matches reference number in appendix A.

7. RADIO EQUIPMENT

7.1 Capabilities and Limitations

7.1.1 The primary capability of radio communication is that it can provide communication between two or more stationary or mobile units without the need for physical interconnection. In addition, radios can be made small, light, and therefore portable. Also, radios are more easily installed than any other means of communication required to give the same range and service.

7.1.2 Radio communication systems have several limitations or weaknesses including:

a. Susceptibility to component failure and performance degradation induced by environmental stress.

b. Disruption of communications caused by irregularities in the transmission path induced by ionic disturbances in the atmosphere.

7.2 Effects of Cold Temperatures and Cold Shock on Radio Equipment

7.2.1 The following are some of the effects of low ambient temperatures on radio equipment.

a. Temporary or permanent change of electrical and magnetic characteristics of components.

b. Loss of calibration.

c. Binding of mechanical parts due to ice formation or congealing of lubricants.

d. Embrittlement of mechanical components.

7.2.2 In addition to the cold temperature effects listed above, there are several special effects caused by cold shock which occur when a piece of equipment undergoes a sudden change in ambient temperature. This cold shock occurs, for example, when the equipment is transported to and from heated shelters in cold regions. Cold shock induces differential cooling and condensation. Effects related to differential cooling and condensation are listed below:

a. Rupture of conductors or insulators.

b. Cracking or delamination of finishes.

c. Cracking of embedding or encapsultating compounds.

d. Opening of terminal seals and case seams.

e. Leakage of fluids.

f. Breathing, caused by influx of cold air into the radio set which occurs when the cold-soaked set is turned off. Glass, ceramic, and plastic parts may break if cooled too rapidly.

g. Sweating occurs when a cold-soaked set is brought into a warm enclosure. The moisture which condenses may cause short circuits, or frost buildup if the set is brought back outside without being dried.

7.3 Adaptation of Radio Communication Equipment to Low Ambient Temperatures and Temperature Shock.

7.3.1 General: The above section discusses the general effects of cold temperatures and cold shock on the mechanical and electrical components of radio equipment. This section will describe specific effects of low temperatures, and the adaptation equipment and techniques used to counteract these effects and insure that the reliability of the communication system (power units and batteries, antennas, radios) is sufficient for normal operations.

7.3.2 Power Units: As the temperature goes down, it becomes increasingly difficult to operate and maintain internal combustion engine-driven power units. For a discussion of arctic adaptation kits for internal combustion engines, see para 3.1. If vehicle mounted radio gear (e.g., radio AN/VRC-46 set) is to be operated off of the vehicle's electrical system, the electrical power unit and regulator must be compatible with the electronic equipment in terms of voltage levels and current handling capability. Often, the capacity of a vehicle's electrical system will have to be increased to power both the radio and a vehicle compartment heater used to keep the radio warm.

7.3.3 Batteries:

a. The effects of cold temperatures on storage and dry cell batteries depends upon the following factors:

(1) Type of battery used.

(2) The load on the battery.

(3) The particular use of the battery.

(4) The degree of exposure of cold conditions.

7.3.5 Radio Sets:

a. The radio set itself and its associated equipment (cables, microphones, etc.) are greatly affected by cold and cold shock, and must be protected to insure reliability.

b. Cold and cold shock have various effects on the electrical components of the radio. For example, composition type resistors have positive temperature coefficients of resistance i.e., the resistance goes down as the temperature goes down. Semiconductor components such as diodes, thermistors, and transistors have negative temperature coefficients of resistance i.e., resistance goes up as temperature goes down. The frequency of vibration of crystals used in filters and oscillators is a function of temperature. If a crystal oscillator is not kept at a stable temperature it may undergo frequency drift and disrupt communication. Also, condensation which forms on parts of the radio may cause short circuits and grounds which will disrupt circuit functions.

c. Effects of cold temperatures and cold shock on mechanical components include brittleness, differential contraction, condensation, and thickening of lubricants. Brittleness caused by cold may reduce the effectiveness of shock mounts, and excessive vibration may then destroy the set. Interconnection cables and power cords become brittle and will break if sharply bent. Differential contraction, condensation, and thickened lubrication may cause binding or locking of mechanical tuning trains, plugs, jacks, keys, shafts, bearings, dials, and switches.

d. Equipment which must operate at low temperatures may require winterization to insure proper operation. For example, certain parts of the radio may have to be replaced because of their inability to function at low temperatures. Normal lubricants must be replaced with proper cold regions lubricants[16]. Standard microphone covers should be used to prevent moisture from the operator's breath from freezing on the buttons and perforated cover plate. If standard covers are not available, a suitable one can be improvised from rubber or cellophane membranes, or from cloth such as rayon or nylon fabric. Also, the cover will protect the operator from freeze burn if his lips should touch the microphone.

e. To prevent and reduce the effects of cold shock, equipment should be covered when transported into or out of warm shelters. This will prevent rapid temperature changes by offering some insulation, and will keep moist air off the equipment.

7.4 Adaptation of Radio Equipment to Other Peculiarities of Cold Regions Environment.

7.4.1 The cold regions environment has several other distinguishing characteristics not necessarily associated with extreme cold. Any set of adaptation equipment or techniques to be used in the cold regions must take these characteristics into account.

7.4.2 Solar Disturbances:

a. Magnetic storms of the kind which interfere with radio communication have been correlated with solar disturbances. During a solar disturbance, a cloud of high energy electrons and protons is given off by the sun. Some particles are intercepted by the earth and are deflected by the earth's magnetic field. The particles then concentrate near the polar regions. The moving particles produce a magnetic field of their own and they may collide with gas atoms in the atmosphere causing ionization of the gas (electrons knocked away from the atom) and emission of light (auroras). This ionization changes the electrical characteristics of the atmosphere and disturbs radio communication. Severe static may accompany such disturbances. Also, blackouts and fading which may last for minutes, hours, days, or even weeks, often occur and are caused by changes in the density and height of the ionosphere. These changes affect the height at which the signal is reflected thus causing the signal to return in varying locations.

b. The greatest auroral activity occurs between 60 degrees and 70 degrees north latitude and occurs at intervals of 27 to 28 days[17]. Weekly predictions of expected conditions are published by the National Oceanic and Atmospheric Administration (NOAA) and are available to Communication-Electronics Staff Officers. Due to the high rate of occurrence of these disturbances in the arctic (and antarctic), radio equipment to be used in these regions must be adapted to reduce these effects.

c. The degree to which ionic disturbances affect a radio signal depends on the frequency used to transmit the signal. Low frequency circuits (100-500 KHz) provide the best medium for long distance, point-to-point radio communication because the low frequency ground wave is not seriously affected by auroral disturbances. Higher frequency sets which often utilize the sky wave portion of the total radiated energy must be able to operate over a band of frequencies so that if an ionic disturbance occurs, the frequency of operation can be changed and communication reinstated. Tactical radio equipment operations in the so-called line-of-sight frequency band (30 MHz and upwards) is not affected adversely by auroral activity. The use of VHF and microwave radio relay equipment will provide the greatest degree of reliability for multichannel means of communications in northern areas. Tactical trophospheric scatter radio equipment, when available, is another means of providing multichannel communications up to 300 kilometers[17]. In summary, radios used in the arctic which utilize a skywave transmission path should be equipped with the capability to operate on a wide variety of frequencies. Also, the antennas used with these radios should have sufficient band width to accommodate the range of frequencies that may be used.

7.4.3 Grounding Problems:

a. General. The frozen earth and the presence of an over-layer of light, dry snow makes it difficult to obtain adequate electrical earth grounds. Placement of grounding rods is made difficult by the fact that the earth is so hard to penetrate. Also, since frozen earth has low conductivity, grounding rods are of little use even if installed. The ground resistance is greatest immediately surrounding the rod(s). The ground resistance can be reduced by using multiple ground rods that are interconnected and by pouring a saline solution around the ground rods (USA Corp of Engineers, CRREL, Special Report 82-13[18]). The preference method of emplacing grounding rods is prior to the earths freezing.

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[17] Footnote matches reference number in appendix A.

b. Effects of inadequate grounds. Inadequate grounds lead to several serious problems including:

(1) Static electricity buildup.

(2) Noise.

(3) Unreliable antennas.

(4) Safety hazards.

c. Static buildup. Wind friction and relative motion of two objects may produce a buildup of charge on the objects. For example, charged snow particles may build up large charges on antennas. If vehicles become excessively charged, arcing may occur which may be quite dangerous if the vehicle is being fueled. Buildup of charge on personnel is also possible. If the charge is discharged through sensitive galvanometers or high impedance voltmeters, the instrument will give erratic and inaccurate readings. Static effects can be reduced by attempting to ground vehicles and personnel as well as possible by using a large conductive grid as an artificial ground or by connection to a ground rod placed in frozen ground by explosive techniques. Personnel should keep hands covered by a thin insulating layer when using sensitive equipment to reduce sparking and discharge.

d. Noise interference. Noise interference among a set of equipment located on a surface of snow and ice can be traced to ungrounded noise producers such as dc generators, unsuppressed vehicles, and unfiltered electrical equipment. All noise producers which are intended for use near a receiving station should be isolated as much as possible and bonded to a common point, but they should not, in any instance, be connected to the receiver ground system. Adaptation equipment may include filters on output circuits to reduce noise, and suppressors to limit interference caused by vehicles.

e. Antennas. Antennas are usually grounded to improve the far-zone field pattern and strength. As previously discussed, adequate grounds are often difficult to obtain, and adaptive equipment must be utilized. Adaptive equipment includes counterpoises and ground plane antennas. A counterpoise is a horizontal array of conductors placed below an antenna to simulate a ground plane. Ground plane antennas are antennas which use a set of reflector elements which function similarly to a counterpoise. Counterpoises should be installed high enough above ground to insure that it will not become snow-covered. Deep snow on the system will change antenna tuning.

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[18] Footnote matches reference number in appendix A.

f. Generators. Ungrounded power generators and equipment are a safety hazard. If possible, metal chassis should be bonded to a common point to prevent dangerous voltages from building up between equipment.

5. **Pressure Gauges**. Except where they are essential, pressure gauges in exposed positions should be removed.

6. **Motor Boats.** To prevent damage to the engines and to ensure that they can be started when required, the following precautions should be taken:

a. An external source of heat should be provided to maintain the engines and pipe systems at a reasonable temperature. It may also be necessary, under conditions of extreme cold, to warm the lubricating oil and diesel fuel tanks.

b. When engines are not in use, or at "short notice", the seawater circulating system should be kept empty. Engines with freshwater cooling systems should have them charged with an approved anti-freeze solution. To facilitate draining the system, drain cocks should be fitted where necessary to drain water from any pockets in the system. On account of the fine clearances in the water pump, small drops of water remaining after draining may be sufficient to cause seizure of the pump if the temperature has not been above -2.2°C. To avoid damage to the pump, special measures should be taken to warm the pump before turning the engine.

c. Full use should be made of devices fitted to assist cold starting of diesel engines, such as heater plugs, ether, etc.

610 INSULATION

Thermal insulation should be applied to the shell and bulkheads behind and above switchboards if such areas suffer from condensation. All cold-weather piping and equipment such as fire, sanitary and freshwater systems, soil pipes and freshwater tanks should be insulated where damage to equipment or discomfort to personnel may result from dripping condensate. All ventilation supply and exhaust ducting and heaters, including flanges and joints, must be insulated to prevent sweating and heat loss.

611 GAS CYLINDERS

Pressure in compressed gas cylinders subjected to cold temperatures will drop considerably and may be insufficient for practical use. Therefore, bottled gases should be stowed inside if safety regulations permit. If they are used directly from an outside stowage in cold weather, as much as $2m^3$($75ft^3$) of volume can be lost.

612 BATTERIES

1. Cold temperatures drastically reduce the output of all types of batteries (both dry cells and storage batteries). For example, at -18°C, the ampere-hour capacity of a typical dry cell battery is reduced to about 25 percent of the 20°C rated capacity. At this temperature, capacities of lead-acid and nickel-cadmium storage batteries are down to about 35 percent and 50 percent respectively.

2. The lowest temperature for reliable cranking is about -18°C. The output of all batteries reaches essentially zero at about -34°C to -40°C. The rate at which storage batteries can accept a recharge is also reduced in cold temperatures. To obtain a good recharge in a reasonable amount of time, the temperature of the battery should be about 15°C or higher.

3. The sulphuric-acid electrolyte in a discharged acid battery can freeze at -15°C. If the battery is fully charged, the electrolyte freezing point is depressed to -60°C or below. Freezing may damage the plates, crack the battery case, split the cover-to-case seal or the terminal-to-cover seal, thus leading to electrolyte spillage. Freezing of electrolyte may also form crystals which can pierce separators,

eventually leading to internal short-circuits and premature failure of the battery.

4. The potassium hydroxide electrolyte in a nickel-cadmium battery does not vary significantly with the state of charge and the freezing point is essentially constant at -60°C. Freezing of this type of battery is not a problem.

5. Storage batteries should be kept fully charged and stowed in a heated space or equipped with heaters.

6. Flashlight and other dry cell batteries should be kept warm when not in use.

7. For more detailed information on handling of batteries in a cold environment, see Annex D.

613 SHIP COLD WEATHER SOAKING

1. Ship cold weather soaking is defined as long-term exposure of the ship to sub-zero temperatures and near freezing seas. The ship gradually reaches thermal equilibrium with its environment after about a two to three week exposure. The ship is considered cold-soaked when the heat loss rate drops to the same point as the heat production rate. The net heat transfer rate is zero and therefore the amount of heat the ship contains is constant.

2. When a ship transits from a moderate climate to a cold climate, its exterior and topside equipment will cool down to ambient temperatures. Low seawater temperatures may cause high vacuums in condensers, condensation on air and seawater pipes and low temperatures in cooling systems. Spaces near the skin of the ship and interior spaces containing seawater piping and/or unheated ventilation will cool rapidly, particularly unheated spaces. After an initial rapid drop, air temperatures in these spaces will stabilize into a slow downward drift until the soak is complete.

3. Spaces below the waterline have a low temperature limit of approximately -2.2°C. However, heat is lost more easily at the water/hull interface than at the air/hull interface. One effect of this is that ship's skin temperatures above the waterline may be higher than those below the waterline even though air temperatures are well below freezing. Topside exterior spaces, subject to solar heating, wind and weather, can experience temperatures far below seawater temperatures and wider, more frequent temperature variations.

4. As temperatures in the outer spaces fall, temperature drops will progress toward the ship's interior. In general, once soaking is complete, the spaces farthest from the exterior of the ship will be the warmest; however, the locations and sizes of heat sources and/or whether the fresh air supply is heated will have the greatest effect on which parts of the ship will have cold problems.

5. **Exterior Effects of Soaking**. The exterior of the ship (and all equipment located there) is essentially at the temperature of the environment.

6. Non-Arctic internal combustion engines, such as those found on small boats, will be difficult to turn over without Arctic-grade oil. Engine fuels will thicken and suffer from wax formation. Water in the fuel will freeze causing fuel flow blockage. Diesels, in particular, become increasingly harder to start as the weather gets colder. High fuel viscosity may prevent proper oil flow through the engine, once it has been started. Tighter clearances due to cold-induced contraction can exacerbate these effects. The film of lubricant protecting engine internals and separating surfaces such as journal/bearing and piston ring/cylinder breaks down more quickly at cold temperatures, allowing adhesion (engine seize) and corrosion to occur.

CHAPTER 8

ELECTRONICS AND CHARACTERISTICS OF ELECTRONIC EMISSIONS

801 GENERAL REQUIREMENTS

1. The following is an outline of some of the requirements for electronic equipment applicable to most types of ships:

a. All exposed shipboard equipment should be capable of operating at temperatures down to -50°C.

b. All exposed electronic equipment should be capable of withstanding wind velocities of 100 kt at any temperature down to -50°C.

c. All mechanically operated equipment must be lubricated with low-temperature lubricant and adequate space heating fitted in spaces where this is feasible, e.g., inside radar pedestals.

d. Electric heaters should be installed in inside covers of electronic equipment fitted on weather decks.

e. Insulators should be lengthened approximately 10 percent or the next higher voltage rating over the normal standard as extra protection against shorting caused by ice formation.

f. Antennas should be designed to withstand an ice load, up to 5 cm thick around the component parts of each antenna. The diameter of wire rope antennas should not be less than 1 cm. All whip antennas should be capable of withstanding wind velocities of 100 kt when coated with ice 5 cm thick.

g. Cables and cords should be handled with care to prevent fracturing. At extremely low temperatures, cables should be unreeled in a warm space before use.

802 EXPOSED ELECTRONIC EQUIPMENT

1. With the foregoing requirements in mind, all equipment should be appropriately winterized and preheaters used wherever possible. The practice of lengthy warm-up periods under no-load or light-load conditions is also recommended.

2. Equipment not in regular use needs to be heated periodically to drive out moisture. Waveguides (and other non-pressurized lines where condensation can accumulate) should be fitted with drain cocks and drained at regular intervals. Planned maintenance schedules for ships should include checks of all drain cocks. Waveguide dryers, should be used as directed.

3. Equipment used in exposed positions, then returned to warm spaces for stowage, must be thoroughly dried to remove all moisture. After drying, the equipment should be allowed to reach the ambient temperature of the space prior to stowage.

4. Ice formation can be a hazard on all types of external antennas, causing breakage or changes in antenna characteristics and reduction of operating range. Ice, which has formed should be knocked off with a thin pole. Ice and snow should also be removed from strain insulators to prevent excessive

transmission losses. Wire antennas should be secured loosely, so any slight whip action can crack ice build-up.

803 COLD-WEATHER PREPARATIONS

1. **Antennas**. Radio equipment requires preparation prior to deployment for cold-weather operations. Of particular note is the problem of antenna icing. Antennas should be coated with a silicone/oil-based substance with sufficient on-board stock available for additional coating, if required. Antennas suffer sea-spray icing in the northern latitudes. The thicker the ice on the antenna, the greater the loss imposed on the signal. Factors such as air temperature, salinity of the water, structural shapes, and wind velocity play key roles in the antenna icing process and should be taken into consideration when operating in the area. Utilizing proper preventive-maintenance methods can aid in reducing the amount of ice adhesion that occurs on an antenna. Wiping the antenna down, ensuring that it is free of dirt, and checking the smoothness of the antenna's surface, are procedures, which can be used by radio personnel to prevent icing. Additionally, all radio equipment (transceivers/receivers) should be brought up to technical manual standards prior to deployment It is imperative that all radio equipment be checked and the necessary preventive maintenance be performed on all communication systems.

   a. Test antenna drive motors.

   b. Apply cold-weather grease, after purging old grease, about one week before getting underway. Make sure grounding straps were properly insulated.

   c. Obtain spare antennas and insulators to replace those which may be damaged from heavy weather/ice.

   d. A complete inspection and Planned Maintenance Schedule (PMS) of antennas/topside equipment is strongly advised prior to Arctic operations to minimize need for personnel to work aloft.

      (1) Check rotating antenna heater circuits and cooling systems.

      (2) Verify weather-tightness of exposed antenna components.

      (3) Check operating mechanism on all communications antenna safety switches.

      (4) Check operating mechanisms on all antennas with lowering systems installed.

      (5) Insulate anemometer as much as possible. Hand-held anemometers should be available.

      (6) Inspect wire antennas (HF broadband fans) and slacken if required.

   e. SATCOM antenna pedestal may freeze, preventing the antenna from tracking in azimuth The following actions may be helpful:

      (1) Place temporary heat strip around pedestal

      (2) Place fibreglass insulation and herculite cover around pedestal.

      (3) Place desiccant bags inside pedestal to absorb moisture

(4) Rotate directors/illuminators at low speed every 8 hours. During extreme icing conditions rotate antennas in azimuth and elevation every 30 minutes to prevent the pedestal from freezing..

f. Fill antenna cooling systems with an anti- freeze solution.

g. Fire control radar antenna scanners (the stinger on the director) may ice over on the inner rotating axis, holding the scanner in the conical scan pattern and preventing the spiraling motion in automatic-track mode.

(1) Keep a coating of antifreeze on the areas between rotating and non-rotating areas.

(2) Train the director aft with elevation depressed during freezing conditions.

(3) Install a lightweight, non-reflective cover on the antenna, when Arctic operations are planned.

h. Operate variable-spaced antennas at low speed for a short period before increasing rotation speed. Do not change the direction of rotation or accelerate/decelerate rapidly, until gear trains and drive motors are thoroughly warmed up. Installation of electric heaters in antenna pedestals is recommended

i. Replace oil in the pedestals of rotating radar antennas with oil that will not congeal at low temperatures. Consideration should be given to the installation of oil heaters.

j. Connect the radar antenna pedestal heater to a circuit that will remain energized when the radar set it self is disconnected.

2. **Slow-Moving Mechanical Parts.** Slow-moving mechanical parts, such as shafts and bearing surfaces, will operate more satisfactorily if the surfaces are buffed and polished. Such surfaces should not be lubricated unless this is essential, and even then it should be done sparingly.

3. **Covered Cables**

a. Rubber-covered, flexible cable becomes stiff at temperatures lower than -6°C; the insulation becomes brittle and can crack and shatter rather than bend.

b. Synthetic materials (e.g. polyethylene) are replacing rubber for insulating purposes because of much improved cold-weather characteristics.

4. **Electric Installations**. Electric installations should be made with special care to minimize the effect of cold, moisture, high humidity and stresses due to icing, as follows:

a. Increase wire size of radio antennas to compensate for high winds and ice loading of long horizontal spans. Receiving antennas using small-size wire are vulnerable to damage by ice loading.

b. Install double antenna suspension insulators for transmitting antennas to increase leakage path and to prevent arc-over.

c. Increase the size of mounting brackets and foundations of equipments in ships which may become involved in ice-breaking operations.

5. **Communications Equipment.** Communications equipment for high-latitude operations should include a transmitter with a high-frequency operating range of at least 26 MHz, and another, which will operate on frequencies as low as 175 - 195 kHz. Both of these transmitters must have substantial power capabilities. All transmitters and receivers should be calibrated on the several frequencies expected to be used. To capitalize on the advantages of low-frequency operation and very low-frequency reception during blackout periods, antenna systems additional to those already installed may be required.

6. **Telephones and Microphones**

a. When using telephones or microphones in exposed locations, care should be taken to prevent the speaker's breath from freezing the microphone. In general, the use of portable microphones supplied with a transmitter station, which is in a protected space is preferable to those located in the open.

b. Cover sound-powered telephone boxes.

804 CARE OF EQUIPMENT IN LOW TEMPERATURES

1. In general, special procedures will be required to ensure satisfactory operation of electronic equipment at temperatures lower than -2°C.

2. Dry-cell batteries and electrolytic condensers will not work at low temperatures, but will probably recover and resume normal operation when warmed. Maintenance will be required to prevent corrosion from condensation caused by temperature changes. Components may require frequency readjustment of critical circuits because of changes in electrical characteristics.

3. When temperatures fall below 2°C, heat should be applied to electronic equipment if it is to be ready for immediate use. Batteries and electrolytic condensers, in particular, must be warm if they are to operate efficiently. Continuous operation in the "standby" or "filament" position is good practice as it keeps equipment at the correct operating temperature before plate voltage is applied, and it eliminates condensation inside the equipment.

805 UNDERWATER ELECTRONIC EQUIPMENT

1. Echo-ranging equipment with retracting transducers requires an "ice-gate" to prevent entry of ice into the transducer sea chest.

2. Radar waveguide and ECM antenna masts on submarines should be filled with pressurized nitrogen and the heaters should be continuously energized.

806 PORTABLE POWER SOURCES (FOR ELECTRONIC EQUIPMENT)

1. A small aerosol-type can of ether should be included to facilitate cold-weather starting of portable internal-combustion power-generated equipment.

WARNING

- Extreme caution should be exercised to limit the quantity of ether injected in both gas-engine carburators and diesel engine air intakes.
- To avoid the possibility of frostbite, do not allow ether to come in contact with exposed body areas.

2. If equipments are to be shut down or left turned off for extended periods, the lubrication oil should be drained while the engine is hot, then stored inside the ship or personnel shelter along with the starting batteries, if so equipped. Often it is more advantageous to leave engine-starting batteries inside and extended cables outside to the generator.

807 MAINTENANCE (PERSONNEL PRECAUTIONS)

1. No maintenance aloft should be attempted unless an emergency condition exists, and then only after rigging an appropriate canvas windscreen protection cover against wind-chill, and installing portable heaters inside to allow maintenance personnel an opportunity to remove gloves, masks and attach safety harness, prior to attempting any electronic-type repairs. (Solder will not blow at-20øC using conventional irons.) Gloves should be donned prior to leaving the shelter, to keep hands from freezing to ladder rungs or handrails.

2. Safety belts/harnesses must be worn when working aloft. Positive footing is never available aloft in northern waters and becomes more pronounced when personnel are required to wear cumbersome clothing and footwear.

3. The installation of communication whip antennas in the vicinity of smoke stacks or boiler room uptakes usually prevents the formation of ice. However, periodic cleaning is necessary to remove soot accumulations and prevent degradation of antenna performance. The cleaning aspect does not present a problem when the whips are of the retractable type and access to the top of the stack is gained through an internal trunk-and-scuttle arrangement. Breathing masks and safety belts/harnesses must be worn at all times to prevent smoke and stack gas inhalation and to conform to "safe working practice aloft" criteria.

808 COMMUNICATION CHARACTERISTICS

1. Radio communications beyond "line-of-sight" limits in the Arctic pose certain problems that occur only rarely at lower latitudes. These problems are mainly caused by ionospheric disturbances which affect the behaviour of radio waves in the Low-Frequency (LF), Medium-Frequency (MF), High-Frequency (HF), and Very-High-Frequency (VHF) bands.

2. The standard shipboard transmitter required for high-latitude operations usually covers a frequency range down to 175-195 kHz, depending on the model. At the lower end of the range, the radiated power obtained may be very small, being something of the order of 0.6 percent to 1.5 percent of the rated output power. This is caused by the inability to load the antenna properly because of its short effective length. Radiation is further decreased by the necessarily short vertical section of the antenna, upon which radiation depends. Optimum radiation with current shipboard antennas is usually realized at around 500 kHz, and effective radiation decreases as the operating frequency is decreased. It has been found, too, that in operating the low-frequency transmitter at frequencies in its lower range at substantial power (one or two kW), using a standard shipboard antenna, severe arc-overs and large losses in antenna trunks will be experienced due to high standing-wave ratios, with high voltage occurring at the insulators caused by inadequate effective lengths.

3. For these important lower frequencies to be used during periods of ionospheric disturbances, arrangements may have to be made to install temporary transmitting antennas of the greatest length and height practicable. The possibility of paralleling existing antennas in series might be considered, and emergency use of balloon suspension should not be overlooked.

809 ARCTIC ANOMALIES

1. Auroral Zones and RF Interference

a. Zones of extreme RF interference and "electronic storms" become increasingly prevalent and severe in higher latitudes. Such "auroral zones" are believed to be due to charged particles ejected from the sun and deflected by the earth's magnetic field.

b. It has been noted that the frequency and severity of electrical storms vary directly with the number of sun spots observed on the sun. Communications in high latitudes are affected both by electronic storms and ionospheric disturbances. In HF/MF bands, propagation becomes erratic; the highest usable frequency decreases and the lowest usable frequency increases. Transmitters and receivers will fade. At times, communications black out completely and may remain out from a few minutes to several days. On the other hand, communications on VHF/UHF circuits may extend beyond the line of sight. Radar may similarly be rendered useless for brief periods, or its range extended by ducting.

c. A communication coordinating circuit should be included in all communications plans. The coordination circuit should be covered using narrow-band and wide-band secure voice equipment cryptographic systems.

2. **Antenna Icing**. Radio equipment requires preparation prior to deployment for cold-weather operations. Of particular note is the problem of antenna icing. Antennas should be coated with a silicone/oil-based substance with sufficient on-board stock available for additional coating if required. Antennas suffer sea- spray icing in the northern latitudes. The thicker the ice on the antenna, the greater the loss imposed on the signal. Factors such as air temperature, salinity of the water, structural shapes, and wind velocity play key roles in the antenna icing process and should be taken into consideration when operating in the area. Utilizing proper preventive-maintenance methods can aid in reducing the amount of ice adhesion that occurs on an antenna. Wiping the antenna down, ensuring that it is free of dirt, and checking the smoothness of the antenna's surface, are procedures which can be used by radio personnel to prevent icing. Additionally, all radio equipment (transceivers/receivers) should be brought up to technical manual standards prior to deployment. It is imperative that all radio equipment be checked and the necessary preventive maintenance be performed on all communication systems.

3. **UHF Communications**

a. Effective UHF ranges are significantly reduced. During heavy snow, absorption and fading are common, further reducing UHF ranges. With unrestricted visibility conditions, maximum UHF ranges are 15 - 16 NM (28-30 km); when visibility is reduced to 1-2 NM (2-4 km), UHF ranges are reduced to 10-12 NM (19-22 km).

b. Few incidents of apparent UHF black-out have been noted. However, on some occasions UHF communications have been good with a ship 10 nautical miles (19 km) away, while having no communications with a closer ship.

4. **Satellite Communications**. A major problem is the potential for the satellite receiver antenna to freeze. Communications dependent upon satellites in geostationary, equatorial orbits will be degraded above 70°N because the satellite is near or below the horizon.

5. **Static**. Continuous high-level static is rarely experienced in Arctic latitudes but sporadic noise is common. Irregularly occurring steady rushes of increasing noise frequently signify auroral disturbances on the frequency employed. Generally, LF is less affected by this type of atmospheric noise than HF. Flakes or pellets of highly charged snow are occasionally experienced in the north during periods of high winds. Charged particles of snow driven against metal vehicles, masts, and antennas, discharge with a high-pitched static sound that can be heard on all received frequencies. This form of noise is more severe on aircraft radios than on ground or vehicle stations.

6. **Ground Conductivity.** Ground conductivity in northern areas is generally poor. At HF and below, effective ground-wave ranges are considerably reduced over ice, permafrost or snow-covered terrain. Moreover, the efficiency of an antenna, especially when propagating in the sky-wave mode, is lessened when installed over this kind of ground. Great care must be taken in siting to secure the best available ground, and considerable effort may be needed to build an artificial ground system.

7. **Communications Plans**. Because of the foregoing, the following communication factors will influence the tactical plan:

a. Extended communication ranges, which must be achieved are normally accompanied by a reduction in communication capacity. Normal scales of communication equipment cannot usually be maintained under these circumstances.

(1) Depending on the nature of terrain and other factors, ground rebroadcast stations for voice operation may have to be deployed at very moderate distances. Airborne rebroadcast may be required for greater ranges. Finally, carrier-wave (CW) operation may be necessary for point-to-point communications at still greater ranges or during disturbed conditions.

(2) Range or terrain may dictate the use of sky-wave transmission. Although usually reliable, it is not entirely so due to the unpredictability of atmospheric conditions.

(3) Where a higher degree of reliability is required at sky-wave transmission ranges, normal HF links must be guarded, by parallel LF circuits. Where this is necessary, two stations must be established at each circuit terminal. Extensive antenna systems may be required for continuous day/night operation.

b. Because of the vagaries of sky-wave transmission, much greater attention must be paid to protecting information than is usually the case. When voice codes are inadequate, ciphers must be employed and these are likely to be of the manual type. Manual enciphering is time-consuming and handling times are in proportion to the length and number of messages being transmitted.

c. In northern areas, the siting of headquarters to gain the extended communication ranges is critical. Detailed ground reconnaissance and testing will probably be necessary to find adequate transmission sites. In the absence of suitable retransmission facilities, a major headquarters or base should not be deployed to a remote locality until a satisfactory site has been determined

CHAPTER 6

COMMUNICATIONS

SECTION 1 - INTRODUCTION

General

1. Military operations in the north are characterized by the employment of forces beyond the range of mutual support, and at considerable distances from controlling headquarters and administrative bases. Because of this dispersion, much greater use must be made of radio at longer ranges than in more conventional operations.

2. Despite a general lack of infrastructure in the north one of the more highly developed aspects is communication systems. Communication liaison with other agencies will greatly enhance operating capabilities. Northern Region Headquarters (NRHQ) has prepared a document, Communication Supplement on Facilities North of 60°, which should be consulted by appropriate staffs.

3. Aircraft can assist in overcoming communication difficulties caused by terrain and extreme climatic conditions by acting as airborne relays and providing air dispatch service.

4. Subsequent articles describe the factors affecting the provision of communication in the northern regions of North America with special reference to the areas affected by the north magnetic pole.

Environmental Problems

5. High-frequency (HF) transmission and reception, while capable of spanning the extended distances dictated by tactical requirements is subject to interference by magnetic storms, aurora borealis, and ionospheric disturbances which may completely black out reception for hours or even days. Transmission and reception under most conditions is possible, however, providing proper installation and operating procedures are followed.

6. The combined effect of terrain, cold, ice, dampness, and dust on communication equipment increases maintenance and supply problems to the extent that the utmost effort of operators and repair personnel is required to provide satisfactory communications.

SECTION 2 - RADIO COMMUNICATIONS

Propagation Characteristics

7. Radio communication in norther latitudes suffers from propagation difficulties, and exceptional planning steps are essential. Emphasis must be placed on the selection and use of proper frequencies. Use should be made of radio propagation graphs, charts, and prediction data for this purpose. Channel evaluation techniques should be used on northern HF circuits to the extent that equipment make this possible. Even when sophisticated sounding equipment is not available, simultaneous transmissions on several frequencies (similar to the "Fleet Broadcast") from a base station provide quite an effective means for out stations and mobiles to select the best frequency.

8. The transmission of a radio signal from a transmitter to a receiver can occur essentially in one of two ways: by a direct path between the antennae of the transmitter and receiver, called the ground wave, or by reflection from a layer in the upper atmosphere or ionosphere, called the sky wave. Since the reflective power of the ionosphere varies with the frequency and the time of day, there are limitations imposed on the frequencies which can be used. At higher frequencies (over 40 MHz) most of the energy in radio waves passes through the ionosphere and is not reflected.

9. Tactical radio equipment operating in the so called line of sight band (30 MHz and upwards - the frequency-modulated (FM) series of the tactical radio sets are included in this band) is not adversely affected by auroral activity, except as noted in this paragraph. In fact the greater ionization in the upper atmosphere which takes place during aurorals will on occasion increase the range of tactical FM sets. The use of very high frequency (VHF) and microwave radio-relay equipment will provide the best means of short-range communication in northern latitudes. Auroral reflected signals may disrupt VHF communications, especially amplitude modulated (AM) voice.

Auroral Effect

10. The reflecting properties of the ionosphere are directly related to the density and uniformity of the earth's magnetic field. This is in turn affected by the position and radiation activity of the sun. In-so-far as radio communications are concerned, sky wave is subject to greatly increased absorption and diffusion. This results in fading, distortion, and short term black-out of the received signal during periods of intense auroral activity. The greatest auroral activity takes place between latitudes 60° and 70° North Geomagnetic Latitude, and occurs at intervals of 27 to 28 days with the highest variations being experienced during the fall/winter period. Although all frequencies up to HF are affected they are not all affected to the same degree.

Ionospheric Disturbance

11. The effect of solar storms and disturbances on the ionosphere is world-wide, however, in arctic areas they tend to be very severe, and are felt almost instantaneously with the occurrence of the solar storm. One type of disturbance termed polar cap absorption, which is caused by solar

flare activity, can result in a complete black-out on sky wave and scatter systems for periods of several hours, and on HF during severe disturbances for several days. The effect of these storms can be greatly magnified when they coincide with periods of maximum auroral activity. For polar areas these disturbed conditions can only be predicted in general terms.

Atmospheric Static

12. Continuous high-level static is rarely experienced in arctic latitudes but sporadic noise is common. Irregularly occurring and steady rushes of increasing noise frequently signify auroral disturbances on the frequency employed. Generally low frequency (LF) is less affected by this type of atmospheric noise than HF. Another source of noise is precipitation static. Flakes or pellets of highly charged snow are occasionally experienced in the north during periods of high winds. Charged particles of snow, driven against metal vehicles, masts, and antennae discharge with a high-pitched static sound that can be heard on all frequencies. This form of noise is more often encountered on aircraft radio and vehicle-mounted stations than on ground stations.

13. Very heavy shocks can be experienced from the ground lead in antennae subject to high winds or blowing snow even when the degree of audible static is not great.

Antennae and Grounds

14. Difficulties will be experienced in erecting antennae in the north. The frozen ground makes it difficult to drive the antennae ground and guy pegs, and the ground plate rods. Care must be exercised in handling lead-in and metal mounts since they become brittle in the cold. Vertical antennae are preferred for ground-wave propagation in the HF band, but the use of fractional wave-length whip antennae is not recommended except for short distances. Antenna towers are easily installed on lake or sea ice utilizing toggles deployed through holes drilled in the ice for guy anchors. The underlying fresh or sea water provides a predictable electrical ground.

15. All large horizontal antennae should be equipped with counterweights arranged so as to give before the wire or poles break from the pressure of ice or wind. Wet snow and sleet freezing to the antennae may be removed by jarring the supports.

16. Ground conductivity in northern areas is generally low with ice cap, permafrost, and snow-covered terrain ranking among the poorest anywhere. At HF and below, effective ground-wave ranges are considerably reduced over this type of terrain, moreover, the efficiency of antennae is lessened when installed over this type of ground. Great care must be taken in siting to secure the best available ground, and considerable effort may be needed to build an artificial system. In no instance should more than one transmitter be connected to one ground or counterpoise, nor should electrical noise producing items such as direct current (DC) battery-charging generators or metal walled huts be connected to a receiver ground system.

17. The use of ground-plane antennae and dipoles for tactical radio must be considered in every operational plan. Telescopic type ground-plane antenna masts will increase the range of the tactical radio sets. The requirement to position the antenna at a minimum of 6 m (20 ft.) above

ground level to counter the effects of the highly charged particles of blowing snow is essential in the arctic. Command vehicles mounted with tactical radio sets should be equipped with facilities to use either a ground-plane antenna or a dipole antenna mounted on an elevated mast or tower.

18. The normal working range for vehicle-mounted tactical radio sets is 32 - 40 km. (20 - 25 miles).

Batteries and Power Supplies

19. Although extreme cold effects all electrical and electronic components it has its most serious effect on batteries, eg:

a. Dry Batteries - The conventional dry cell loses efficiency rapidly at low temperature, and decreases in capacity as the temperatures drop below 21°C. The terminal voltage is not affected by cold, but the life capacity is lowered, and the ability to supply a given voltage over a period of time falls off drastically at temperatures below -18°C. However, the capacity of a dry cell may be restored by warming it to the operating temperature. Battery warmers are provided to restore cell capacity, and insulated containers are provided to reduce heat loss during operations. Special cold-weather batteries are now available which permit a much longer life span in temperature down to -40°C. Battery packs for fixed installations such as beacons, radio-controlled runway lights or detection systems can be placed in or below lake- or sea-ice cover to provide a constant temperature environment (0°C to -1.7°C).

b. Storage Batteries - The efficiency of storage batteries varies widely by type. Nickel cadmium batteries have the least variation through the lower temperature ranges, and therefore are a preferred power source. Batteries of the lead-acid type are less effective at low temperatures in that their ability to deliver a rated voltage falls off very rapidly with use. Under these conditions batteries must be kept fully charged at all times as they are liable to freeze. When radios are powered by vehicle electrical systems, great care must be taken to ensure that prolonged or excessive loads do not reduce the potential below that needed to operate the radio or crank the engine.

Electronic Warfare

20. The low temperatures, low visibility, and the lack of ground lines in the northern region impose greater reliance upon radio type devices for command and control of ground combat forces. Radio navigational aids, so necessary because of the scarcity of landmarks, prevailing low visibility, and long hours of darkness are particularly sensitive to EW measures; this is especially true when alternative base stations are few and far between. On the other hand, the enemy must also rely upon electronic aids. A small EW unit properly employed can play a decisive role in northern operations.

21. Operators must be proficient in their trade, and a higher level of training is required so that they can recognize the difference between atmospheric interference and EW jamming.

Tactical Nets

22. Command radio nets must be established first, and priority given to their maintenance throughout the tactical operation. When a unit moves out of ground range of its base of operation, rebroadcast or relay stations must be established or sky wave propagation will have to be depended upon. When it can be anticipated that distances are so long as to preclude communications with equipment normally available, higher headquarters should be requested to furnish communication support. Situations may arise where communications will not meet expectations. Alternative means such as messenger services must always be included in the signal plan.

23. The effects of the environment, including the conditions of the atmosphere, will affect the radio nets at all levels. Loss of contact drills must be initiated, and must be closely followed.

24. The establishment of air-ground nets is of major importance in all tactical operations in northern latitudes because of the dependence on aircraft for airmobile operations, logistical support, observation, and messenger missions.

25. The use of VHF - ultra-high frequency (UHF) radio relay equipment mounted on small tracked vehicles will provide the most reliable means of communications to mobile task forces at unit level. This equipment must have the same characteristics of mobility and concealment as the supported units.

SECTION 6 - PECULIAR OPERATING PROCEDURES

General

36. Standard types of communication equipment can be used at very low temperatures with satisfactory results if precautions are taken, and the equipment is properly winterized. Provision must be made in the operational plan to include the special maintenance requirements necessitated by operations in extreme cold. As a general rule, signal communications equipment should be installed and operated in warm shelters. Warm shelters are absolutely essential for maintenance personnel. The general principle of keeping equipment warm and dry, and following winterization instructions closely will ensure the best possible performance of communication equipment.

Mechanical Malfunctions

37. There are three causes of mechanical malfunctioning in communication equipment:

a. Contraction - The various metals in a piece of equipment contract differently as the temperature falls. Plugs, keys, jacks, valves, shafts, bearings, and dials are subject to malfunctioning because of differences in rates of contraction.

b. Lubrication - Normal lubricants and oils become so viscose at low temperatures that they may not furnish adequate lubrication between moving parts. Special lubricants and servicing routines are needed to overcome this problem. Dial mechanisms employing fibre gears require specific attention.

c. Freezing - In addition to the trouble caused by differential contraction, moisture condensation which freezes in such assemblies will also render them inoperative, Moisture condensation caused by localized heating may freeze sub-assemblies during shutdown periods and render them difficult to operate.

Radios

38. Upon exposure to extreme cold, receivers and transmitters adjusted for operations in a relatively warm area may exhibit, in their frequency determining circuits, changes of sufficient magnitude to impair their operation. Low battery voltage will also have a detrimental effect. All radio operators must be trained to make frequent checks for proper frequency setting (should the type of equipment allow).

Microphone Assemblies

39. Moisture from breath freezes on presser switches and perforated cover plates of microphones rendering the equipment inoperative. Microphone covers must be employed, but as an expedient the microphone can be carried inside the parka close to the body. Prophylactics make excellent microphone covers.

HOW TO BUILD A THREE LEG TERMINATED DIPOLE

T3FD

COVERING 160 – 10Meters

Tony KA2UFO 8/2018 REV 1.0 8/29/2018

Introduction

Presented here are design and build notes for a Three Leg Terminated Dipole (T3FD) for 160 to 10 Meters based upon works by Cebik, the BUSHCOMM BBA100 series antenna, info from the HFLINK site and lots of experimentation on my part.

Shown are instructions with photos and guidelines to build a multi-band T3FD antenna for ALE use, a bill of major materials, cost information, ideas and test results.

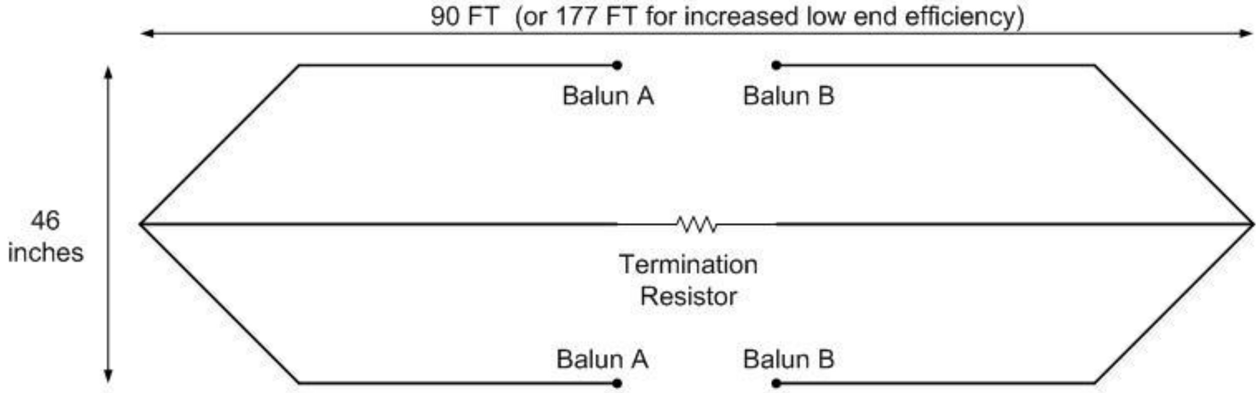
The goal is to help hams build it and have some fun with ALE.

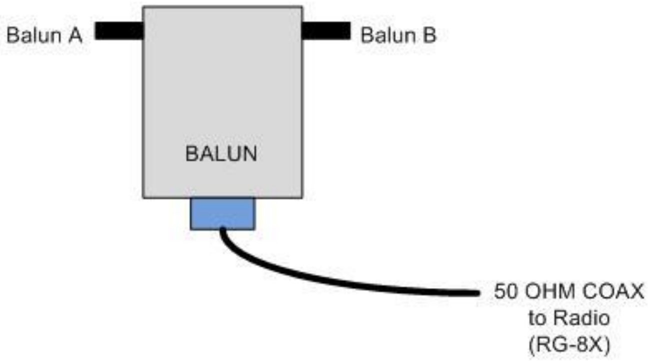
This T3FD works well, and it's easy to build!! If you have room for a 90 FT dipole, try this T3FD.

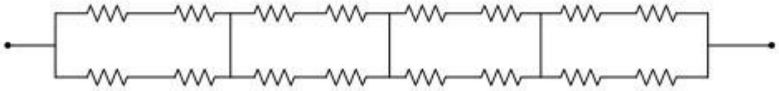
The Balun and termination resistor construction have always been a bit of a mystery and there is plenty of junk science out there, even on some commercial ham sites. I read through everything I could find and experimented with designs found on various sites. The best compilation of information and history I have found is on the HFLINK site and, additionally, the document by Cebik (see ref). The termination resistor is my own concoction.

At first I experimented with the standard 2 leg version (T2FD) like B&W makes. I tried various Balun core types, transformer ratios, termination resistor values, lengths, height above ground, leg spacing, bench testing and on the air testing. The 2 leg version worked OK, but the VSWR was a bit higher on some bands than I expected.   After all, the object is to have wide-band multi-band operation without the use of an antenna tuner. However, from what I have learned from building the T3FD, I can now make the appropriate improvements for the T2FD.

Larry N0OQA told me about his Bushcomm 3 leg terminated dipole (which his is very happy with) and was kind enough to send pictures, performance and VSWR data. After reading data by Cebik on multi-leg terminated dipoles, the three leg version is an efficiency improvement over the 2 leg and not as cumbersome as 4 or 5 leg versions. That's what I wanted to build and share.







TERMINATION RESISTOR: ALL RESISTORS 220 OHM 5 WATT
Metal Oxide Film (OVERALL 880 OHMS 80 WATTS)

T3FD OVERALL LAYOUT

The Three Leg Terminated Dipole can be built in a 27 meter (90 Ft) long or 54 meter (177 FT) long configuration. The 54 meter (177 Ft) long version will have increased low frequency efficiency. I built the 90 FT version due to space limitations and it works down to 160M, soundings are being heard and received on all active bands. These are not resonant antennas so the length and spacing is not very critical.

The spacers are made from 1” PVC pipe, 4 feet long. Spacing of the outside wires is 46 inches, again not too critical. End insulators and center spacer insulators are also 1” PVC pipe. I used a fiberglass rod to make the center support to hold the center insulator assembly in position. A piece of aluminum tubing would be better to prevent skewing from the coax weight. Suspended weight is a concern.

End insulators are 1 Ft long 1” PVC pipe. I drilled three sets of three holes longitudinally along the pipe about 1 inch apart on the antenna side. I then threaded the three wires through three holes each from the far end outside to the center and out the middle of the pipe. There the wires are soldered, a big crimp lug is crimped over the joint and it is wrapped with self-amalgamating rubber tape.

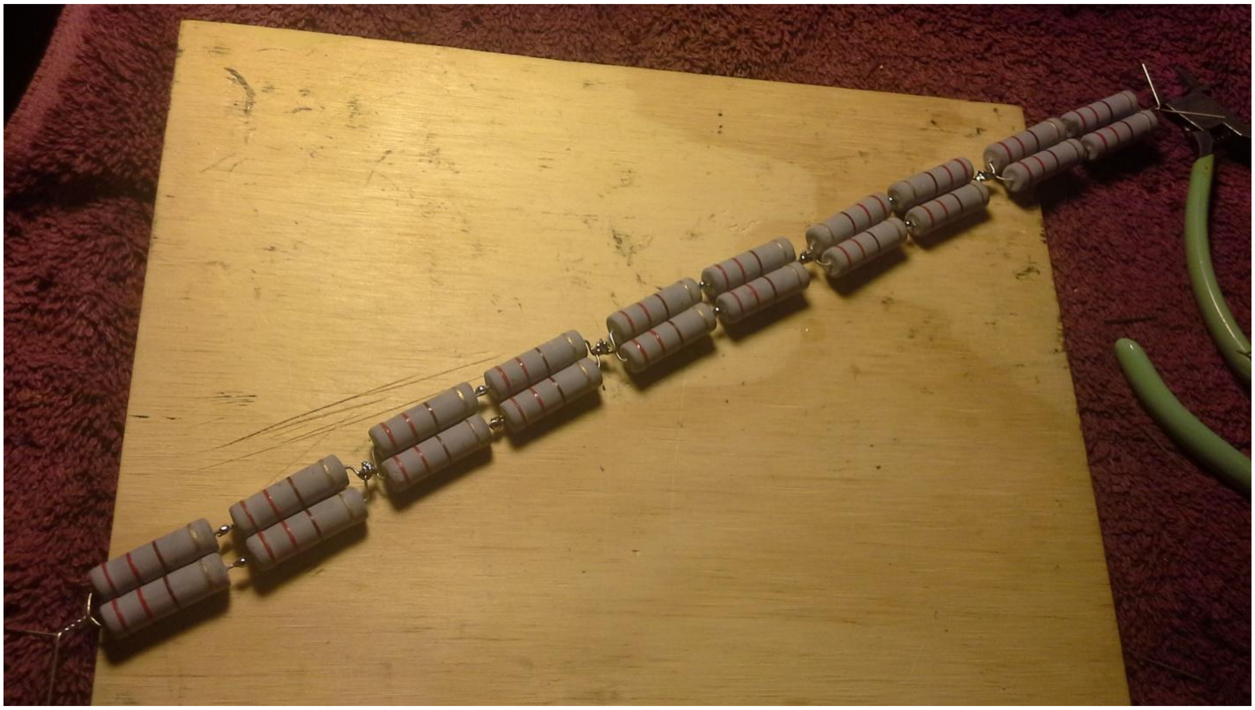
An improved joining method is shown in the pictures using cable clamps and end stop ferrules. A further improvement would be to use a large ferrule to trap all three wires instead of the clamps.

I used PVC for the insulators here as a test for the experiment. Birnbach #47 1W, 1 1/16 inch diameter x 13 inch ceramic insulators or Johnson 136-112 insulators would be best for a heavy duty antenna. Check your hamfests and ebay.

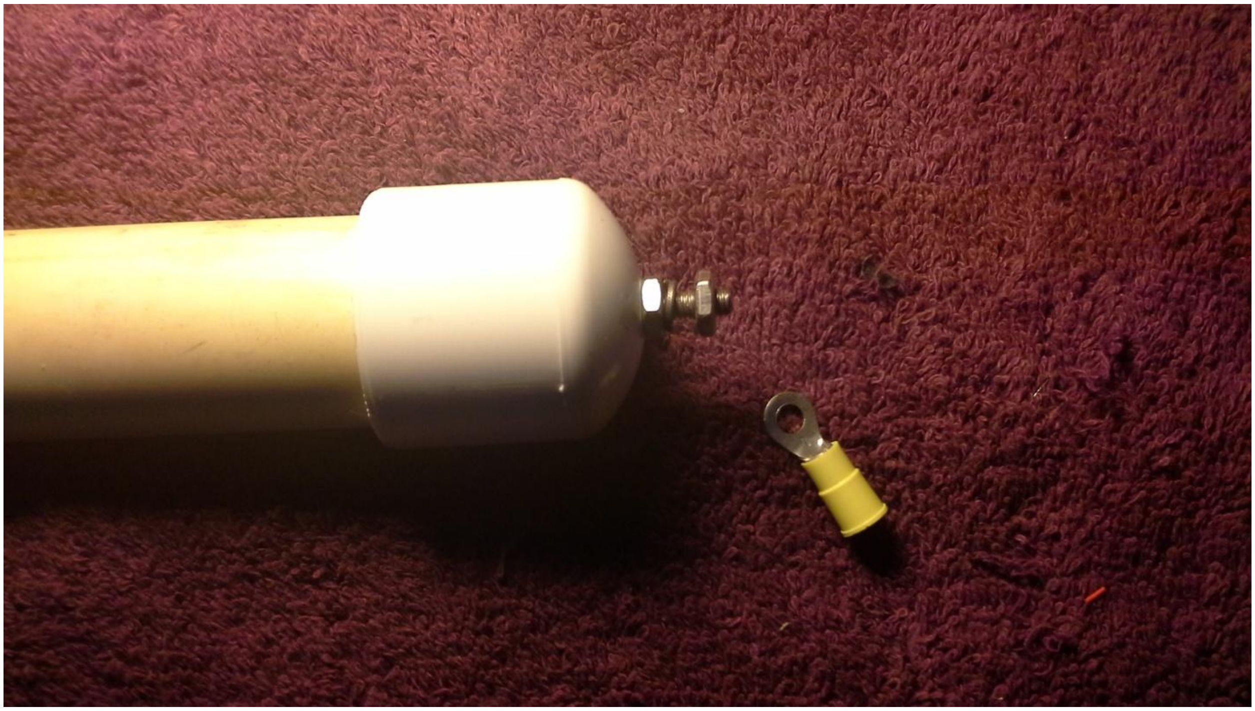
TERMINATION RESISTOR

The termination resistor is built from 16 – 220 Ohm 5 Watt Metal Oxide Film resistors in a parallel series array to produce an 880 Ohm 80 Watt load. These are soldered together as shown in the picture and inserted into the 1” PVC pipe….end wires are attached to the stainless screw lugs and the caps are held in place with stainless sheet metal screws. They are NOT glued on to allow repair or experimentation. 1/16” drain holes are drilled at the bottom edge of each end cap.

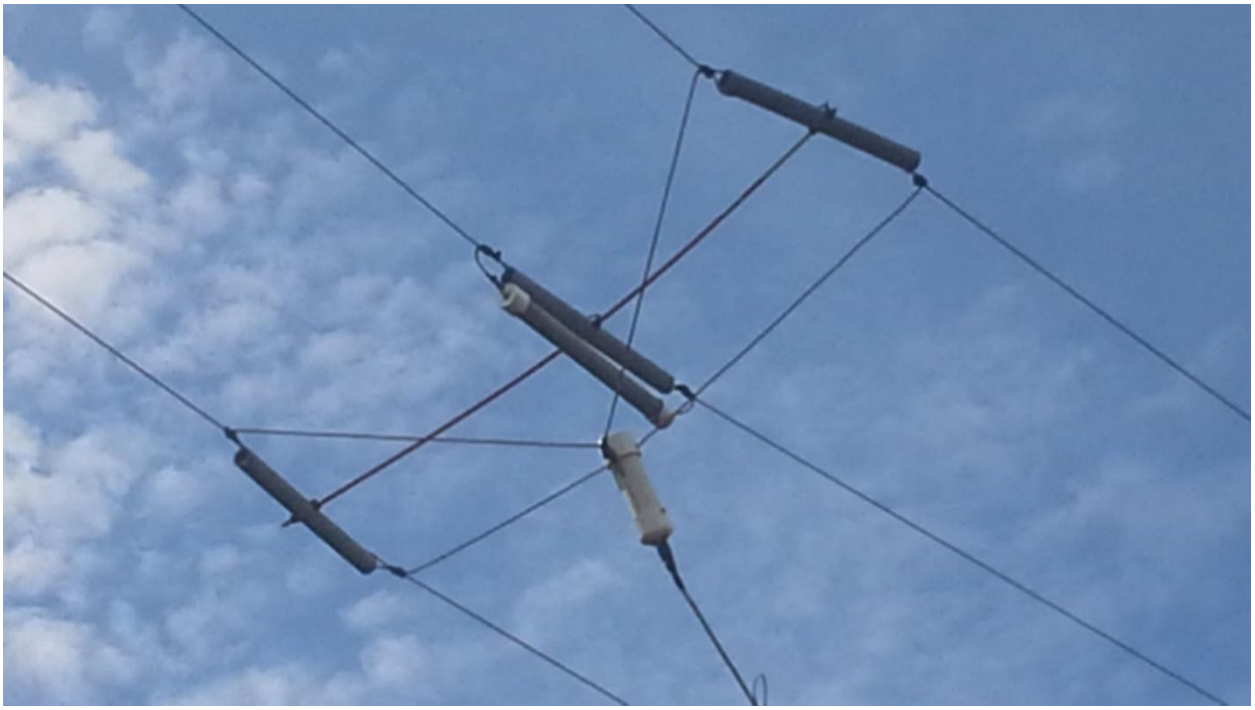
Note: The picture shows 20 resistors (5 banks of 4), one more bank of 4 resistors than is needed; the picture was from an earlier experiment. Be sure to use only 4 banks of 4 resistors and measure the assembly with an ohm meter before assembly. Mine measured 865 Ohms. See the diagram.



Termination Resistor Array (Note: This has 5 banks of 4, we want 4 banks of 4 resistors)



This is one end of the Termination Resistor pipe and Ring Lug. Hold the cap in place with a stainless screw and seal the cap with tape or coax seal. Also use coax seal on the bolt and ring lug and drill drain holes.



The Termination Resistor hangs below the center insulator. It's the gray pipe with white end caps.

BALUN

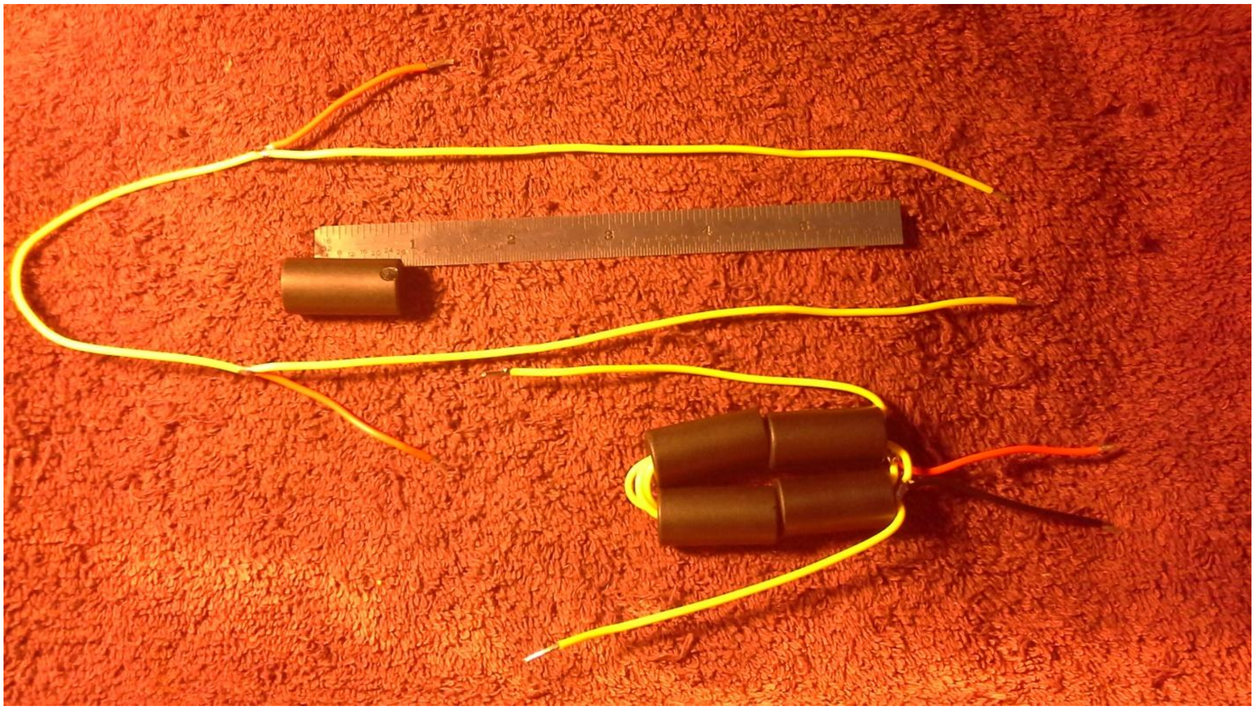
The Balun is a modified version of the KISS Balun by K6KBE which uses 4 #31 ferrite cores and 16ga Teflon coated wire.   This Balun tested the best of all I have tried and is super easy to build. It actually works past 50 MHz!

See this link for more detail:

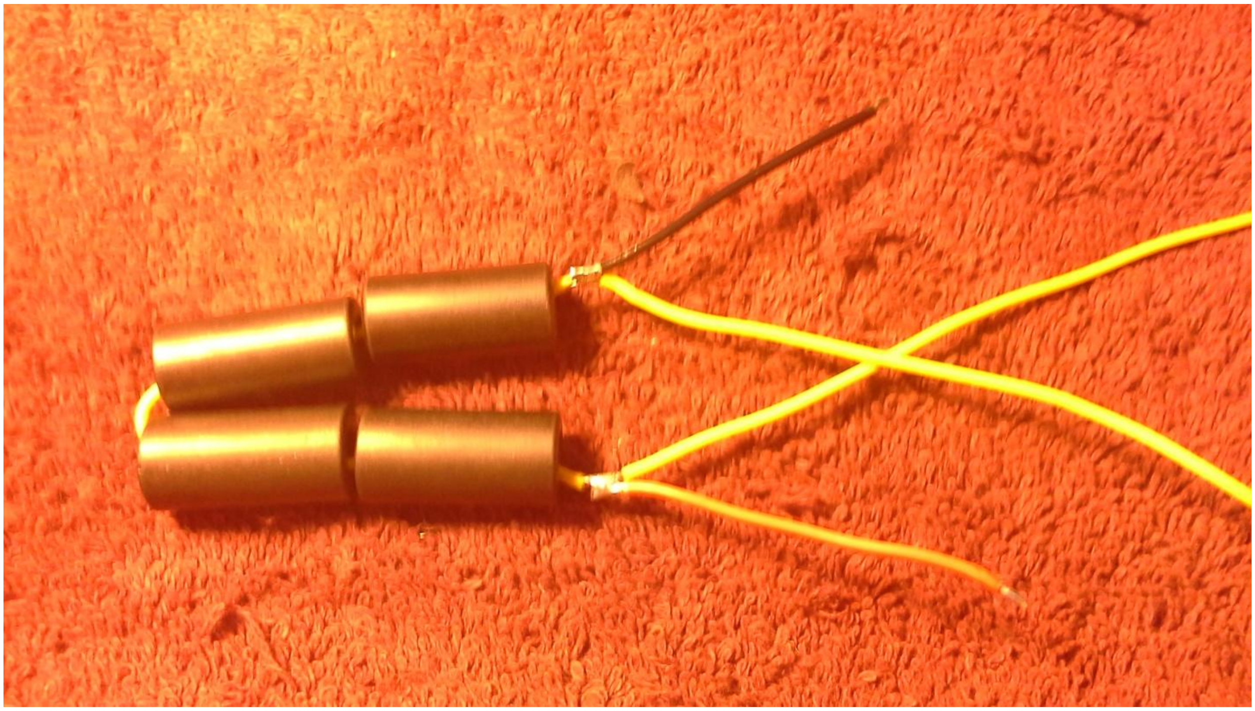
HFLINK.com/Antenna

The modification is to make it a 9:1 rather than a 16:1 ratio. This is simply done by making three passes through the cores instead of 4 passes. The transformer ratio is the square of the turns ratio, so a 4 turn is 16:1 and a 3 turn is 9:1. So easy.

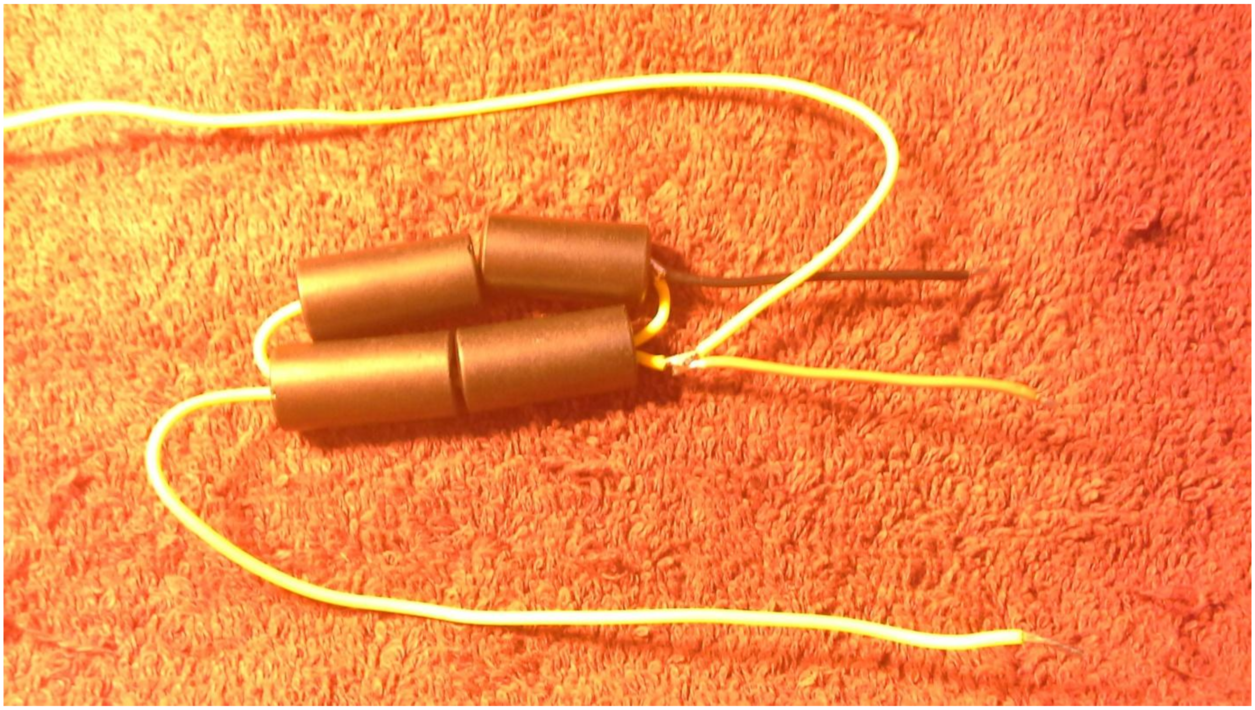
The Balun is built into a 1 1/2" PVC pipe with caps. The caps are held on with stainless screws, not glued, to allow for repair and experimentation. Drill two 1/16" drain holes in the bottom by the SO-239.



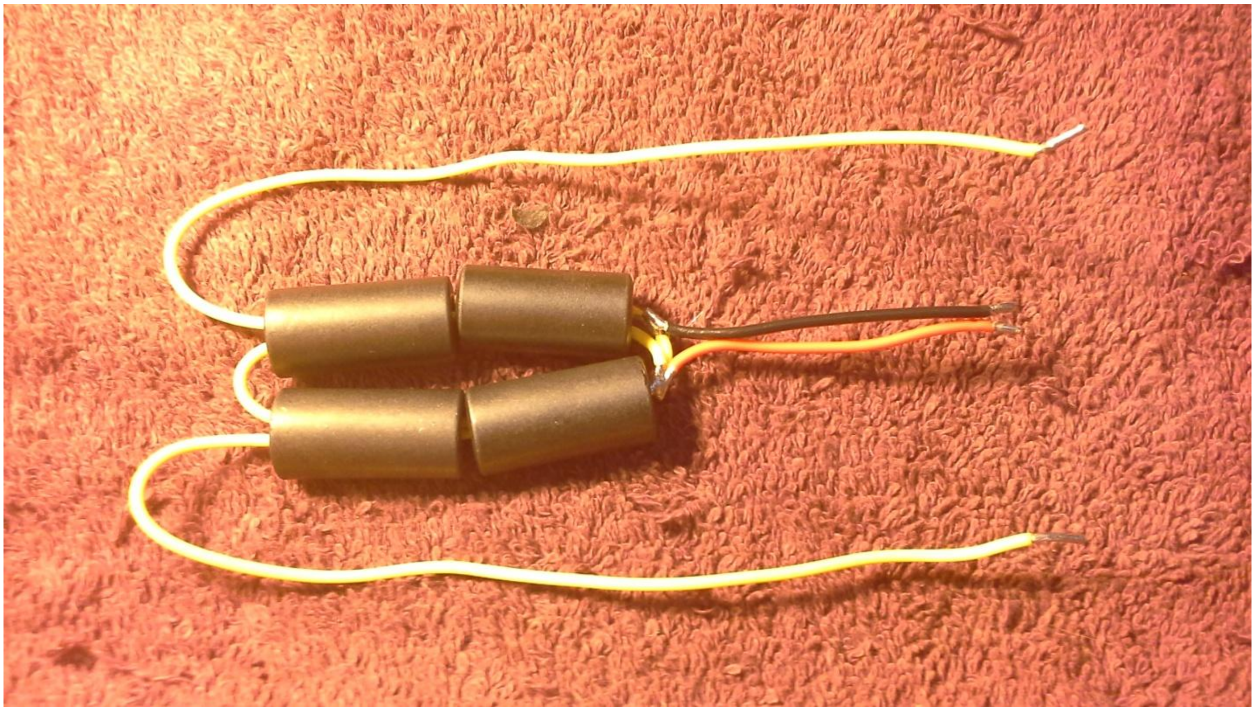
Overall view of the cores and Teflon coated wire assembly for the 9:1 version of the KISS Balun.



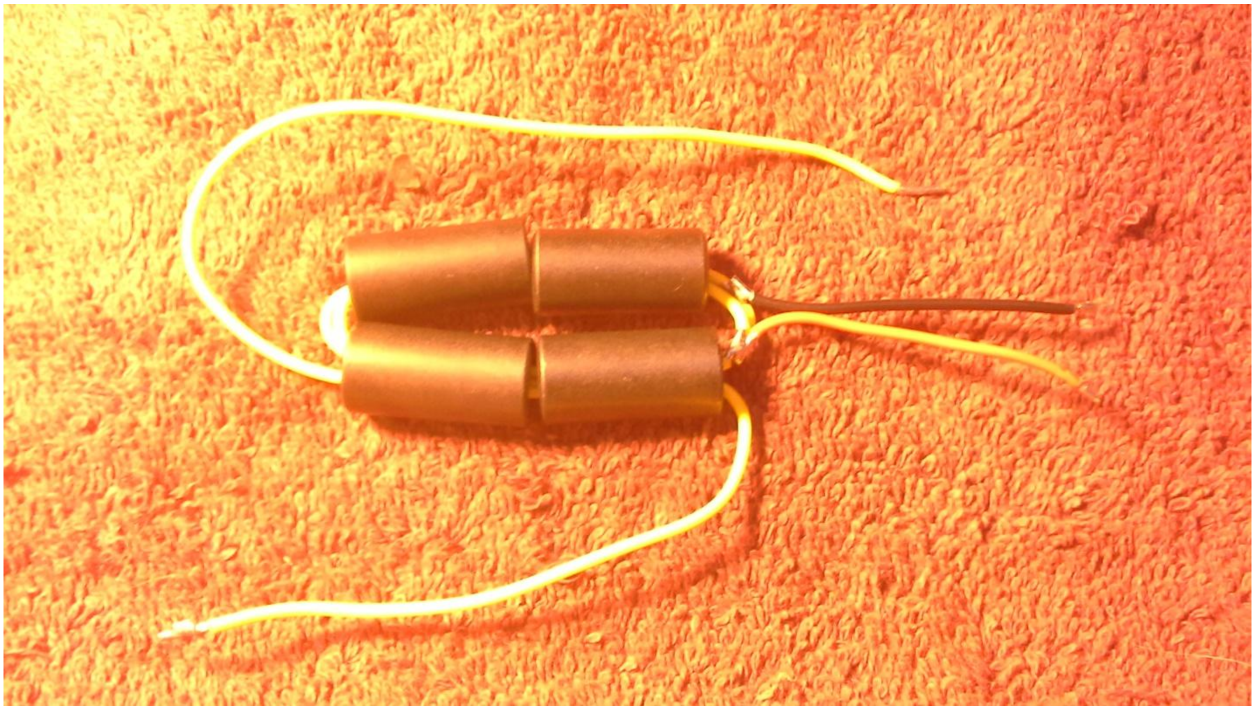
Step 1: Insert the wire assembly through the pairs of cores as shown. Keep wires snug.



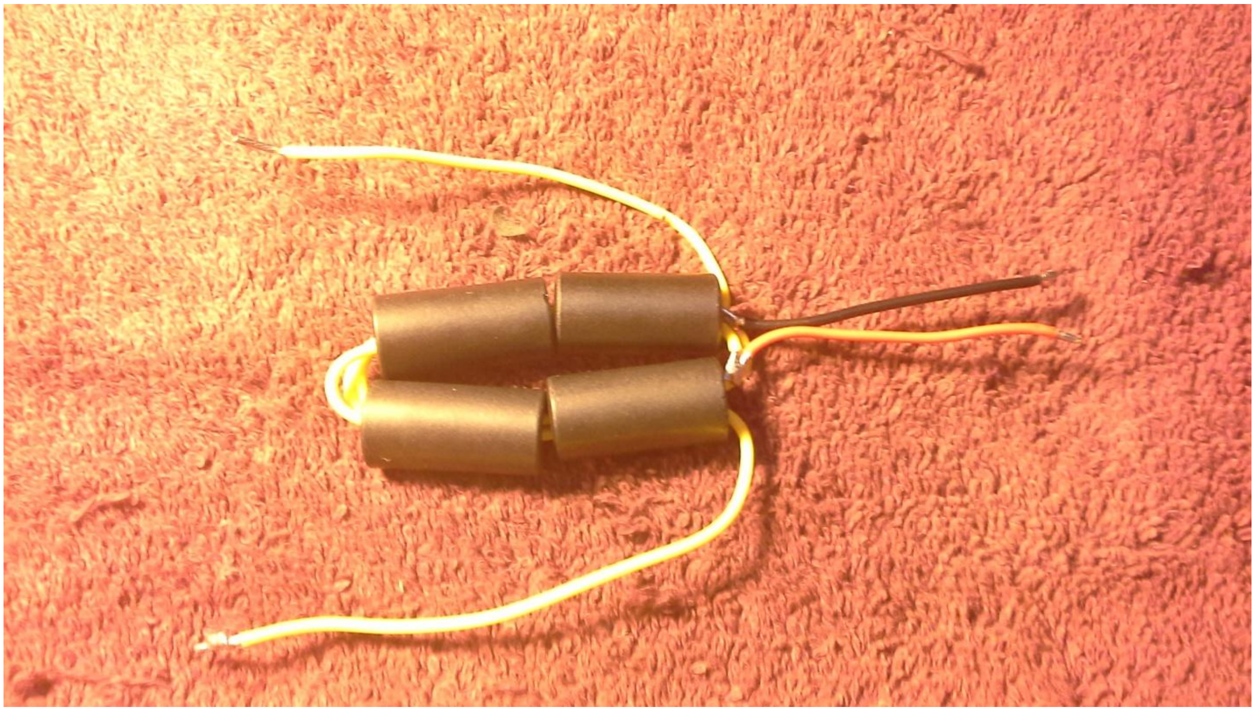
Step 2: Take the upper tail and insert it through the bottom cores.



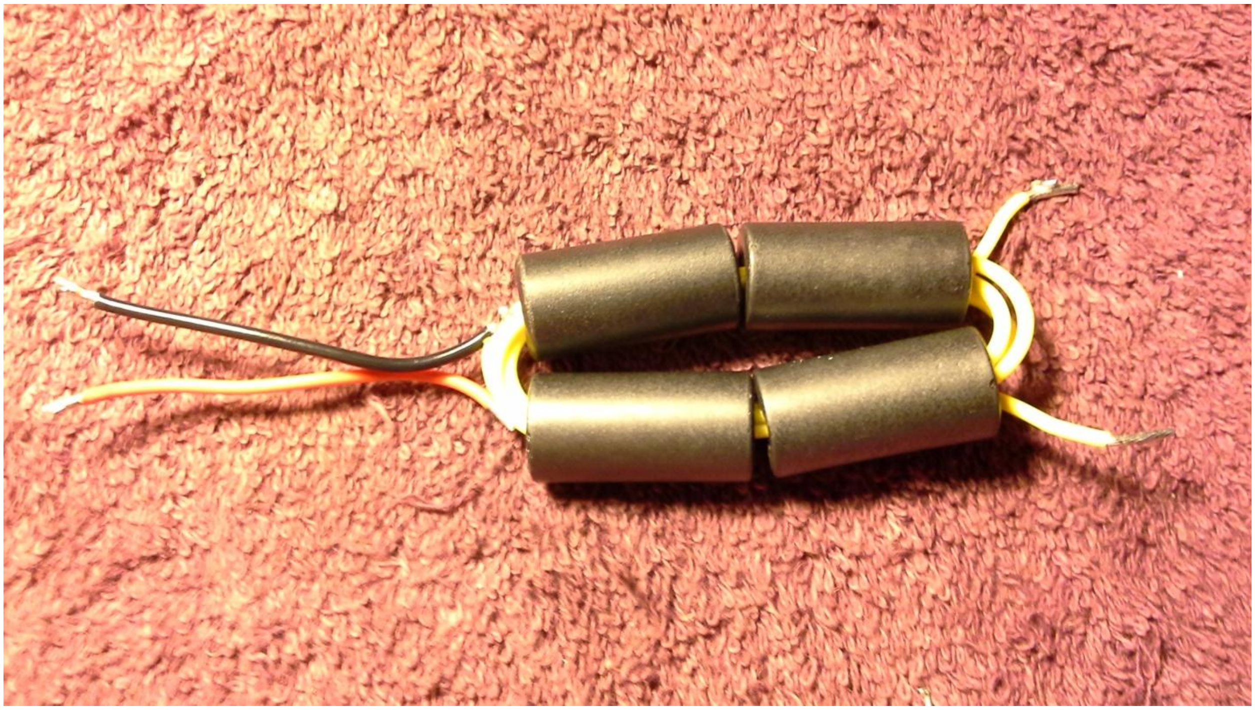
Step 3: Take the lower tail and insert it through the upper cores. Keep wires snug.



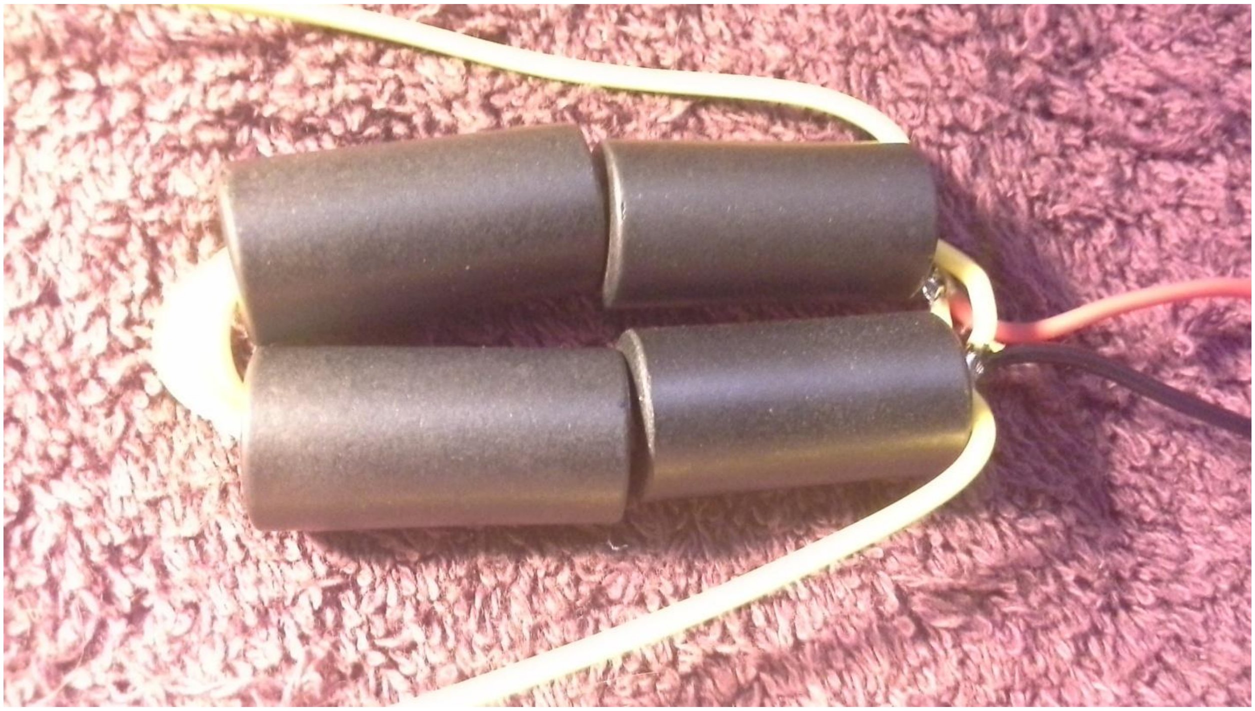
Step 4: Take upper tail and insert it through the lower cores.



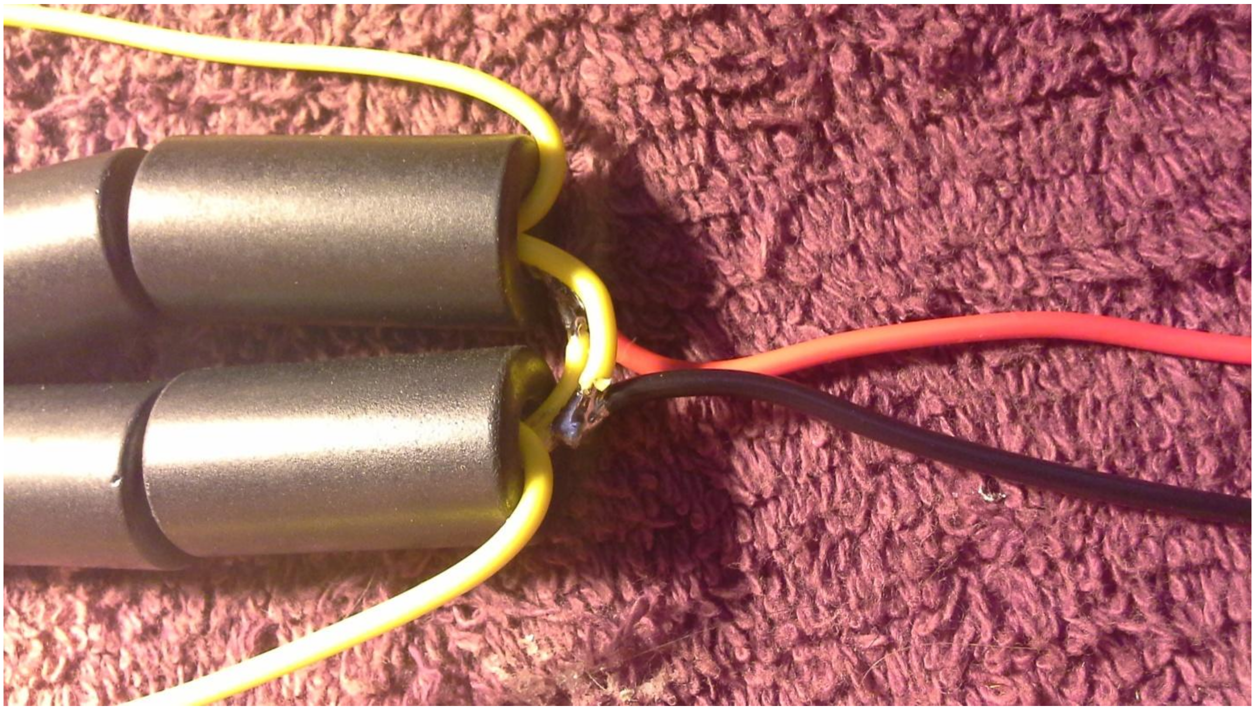
Step 5: Take lower tail and insert it through the upper cores. Snug up the wires.   9:1 Balun is complete.



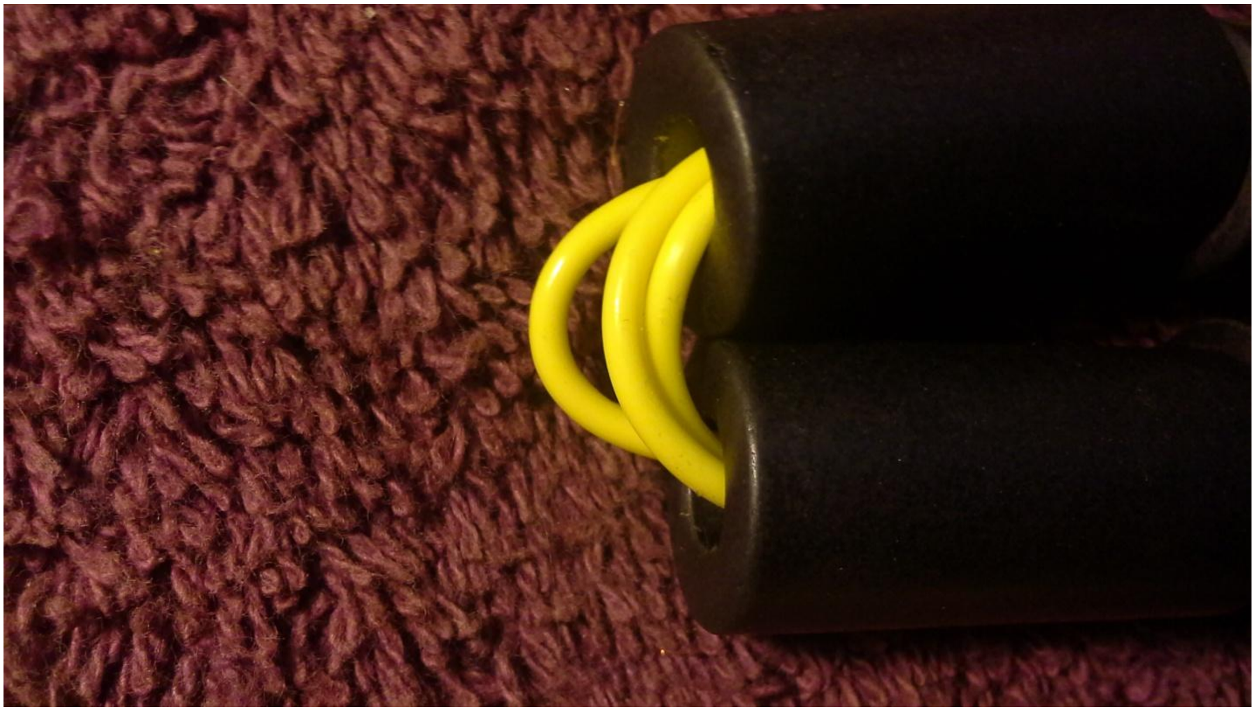
The original KISS Balun with 4 turns through the cores for 16:1 ratio.



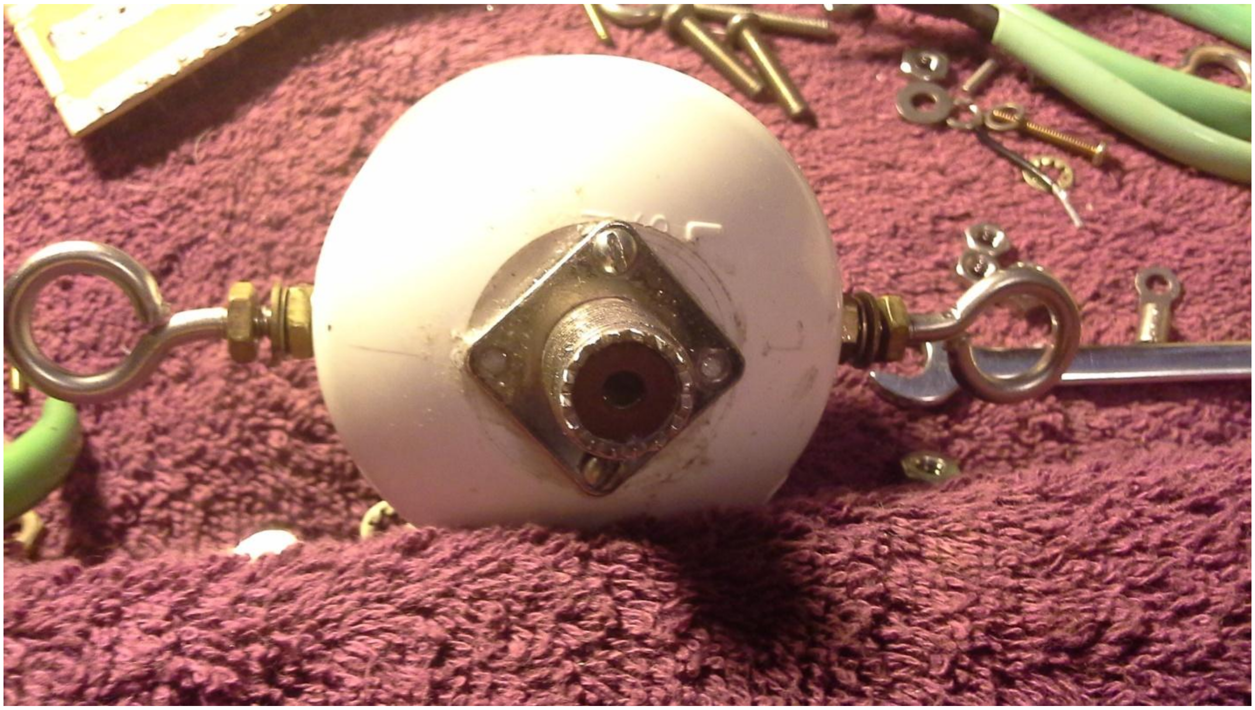
Pull one pass back out of the cores of the original design to make it 3 passes for a 9:1 Balun.



Red and Black go to the SO-239, Yellow go to the outer wires of the T3FD.



Three passes through the cores makes it a 9:1 Balun



Typical installation of a SO-239 into an end cap. Drill two drain holes as well.

ASSEMBLING THE ANTENNA

These are non resonant antennas so the length and spacing is not super critical.   You will need some assistance. Lay out the spacers and insulators out on the lawn and stake them in place at the correct distances.

Regardless on the approach used to install the wires, three wires joining at the end insulator versus a continuous outer wire and separate center wire, it is important to remember to slide on the appropriate ferrules as you go.

Once the wires are in place temporarily wire (zip) tie them at the insulators so that everything can be measured and the wire lengths adjusted.

Crimp and finalize the end and center insulator connections first.   You can slide the spreader back and forth a bit to equalize the tension on the three wires, then crimp the ferrules to hold it in place.

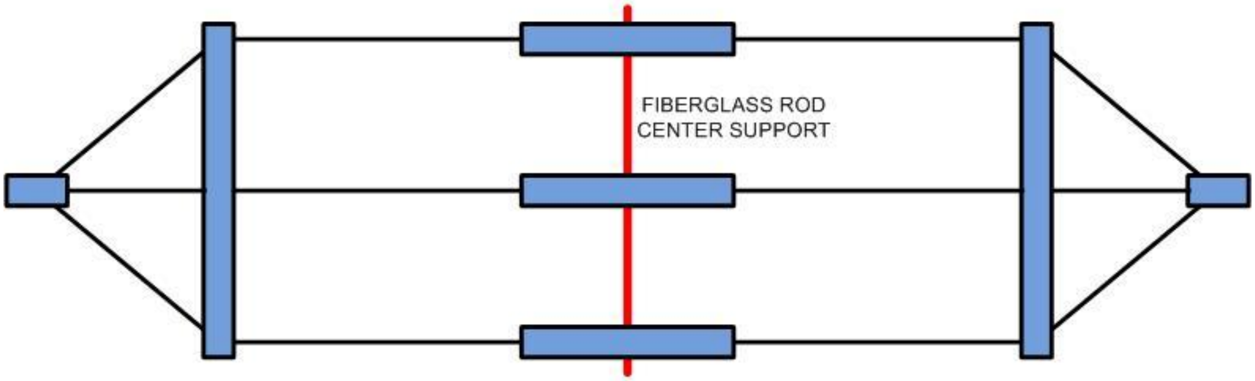
Leave at least 2 ft of wire after the center insulators to make the drop to the Balun which hangs below the center insulator system on the wires, and at least 1 ft of wire for the drop to the termination resistor.

Place the termination resistor pipe a few inches below the center wire insulator and trim the tails on the center wire to reach the connection screws. Crimp on ring lugs, solder if you wish, and attach the lugs to the termination resistor. Use coax seal and tape to seal up this connection. Make sure the tiny drain holes at the ends of the termination resistor are facing down.

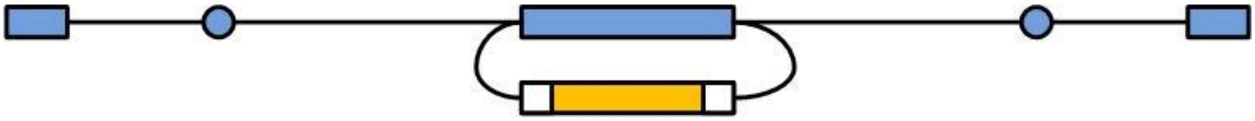
Attach the Balun to the outer wires by cutting the wires to equal length where they all meet when held together below the center insulator assembly, so that the Balun will hang below the center assembly 18 to 24 inches, not critical. The outer wires from one end of the dipole get crimped together on a heavy duty ring lug, same for the other side. Wrap each pair with tape to enhance the mechanical integrity of the joint and attach to the lugs on the Balun. The weight of the Balun and coax hangs on these joints, so make sure they are solid.

The T3FD is now ready to erect and test. Use coax seal on the bolts and coax connector.

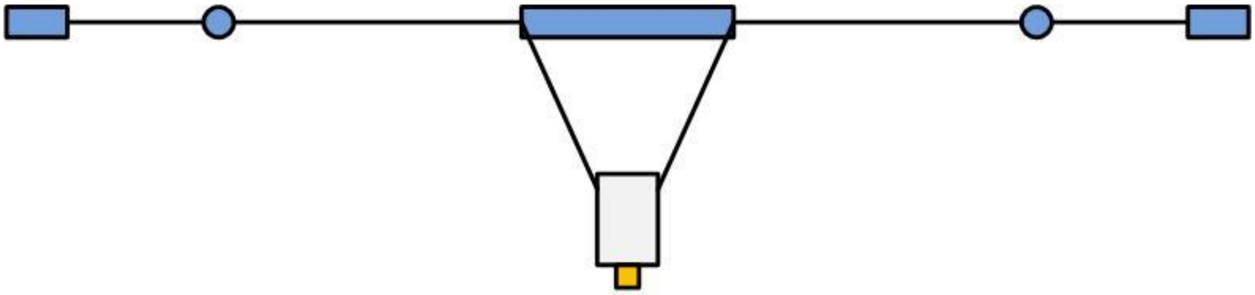
T3FD INSULATOR LOCATIONS



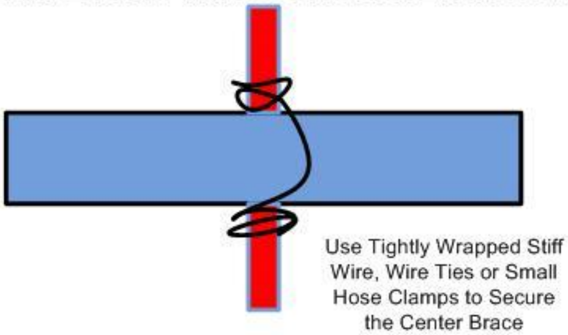
SIDE VIEW OF TERMINATION RESISTOR LOCATION



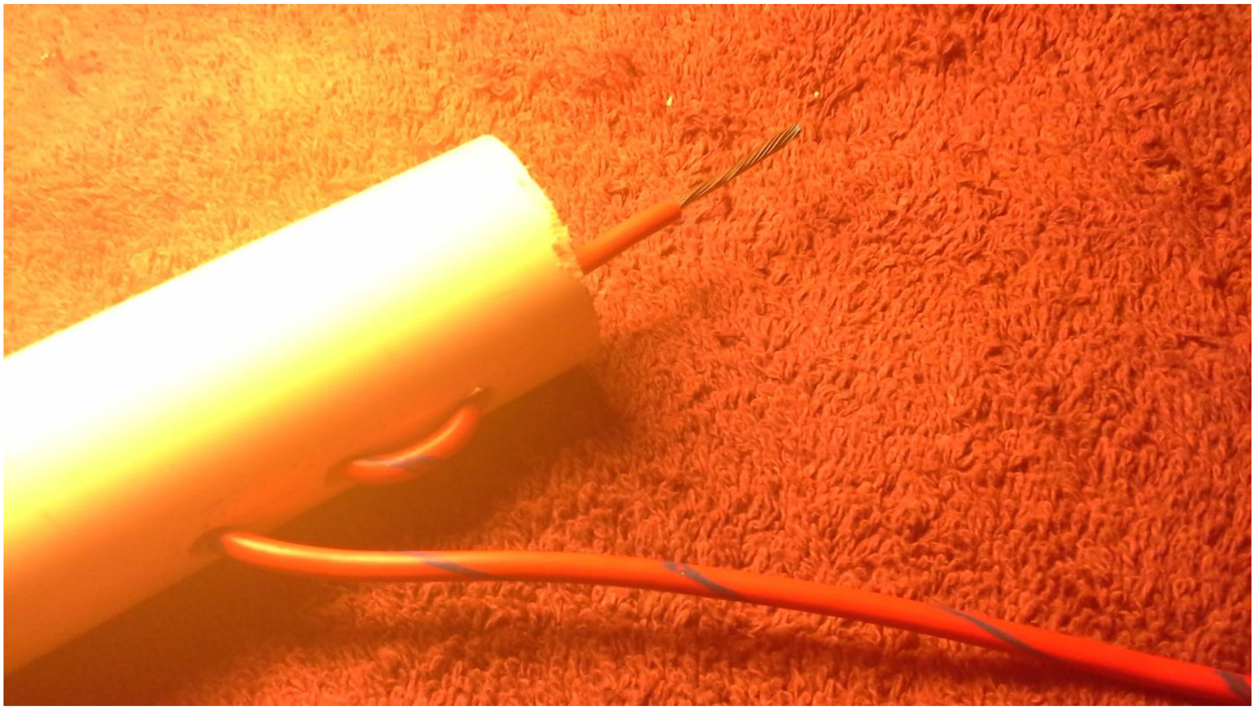
SIDE VIEW OF BALUN LOCATION



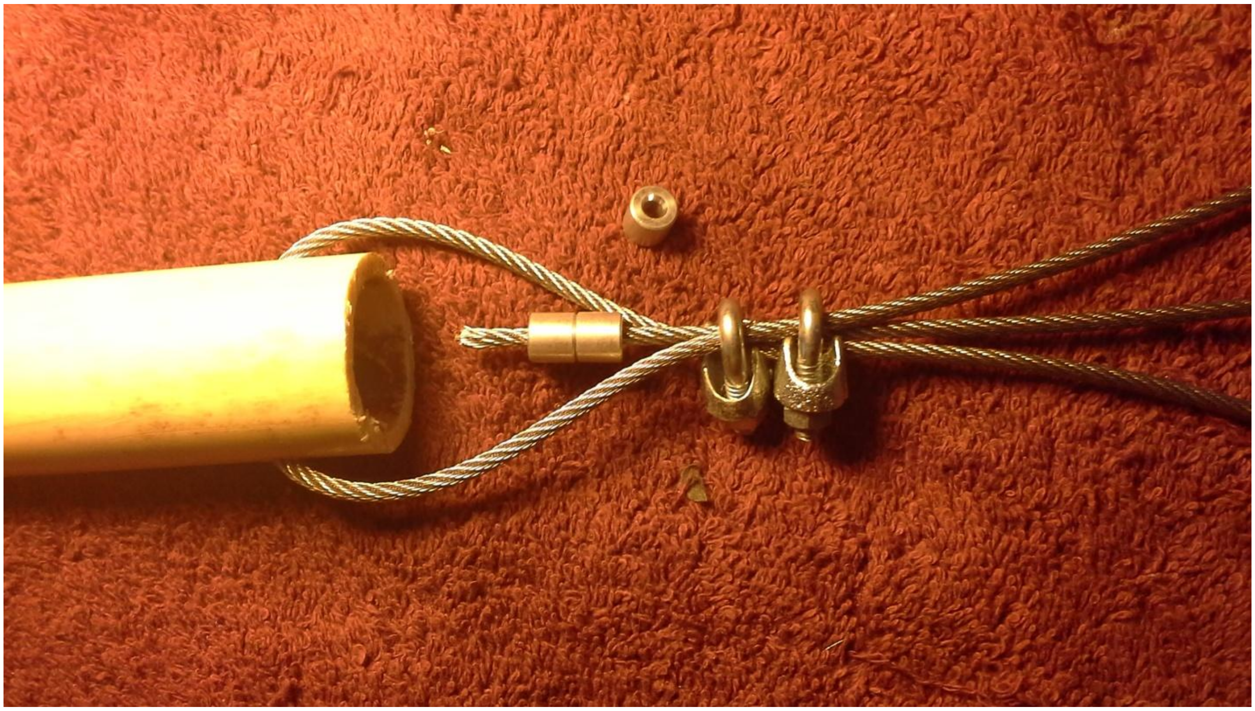
CENTER BRACE PASS THROUGH CENTER INSULATORS



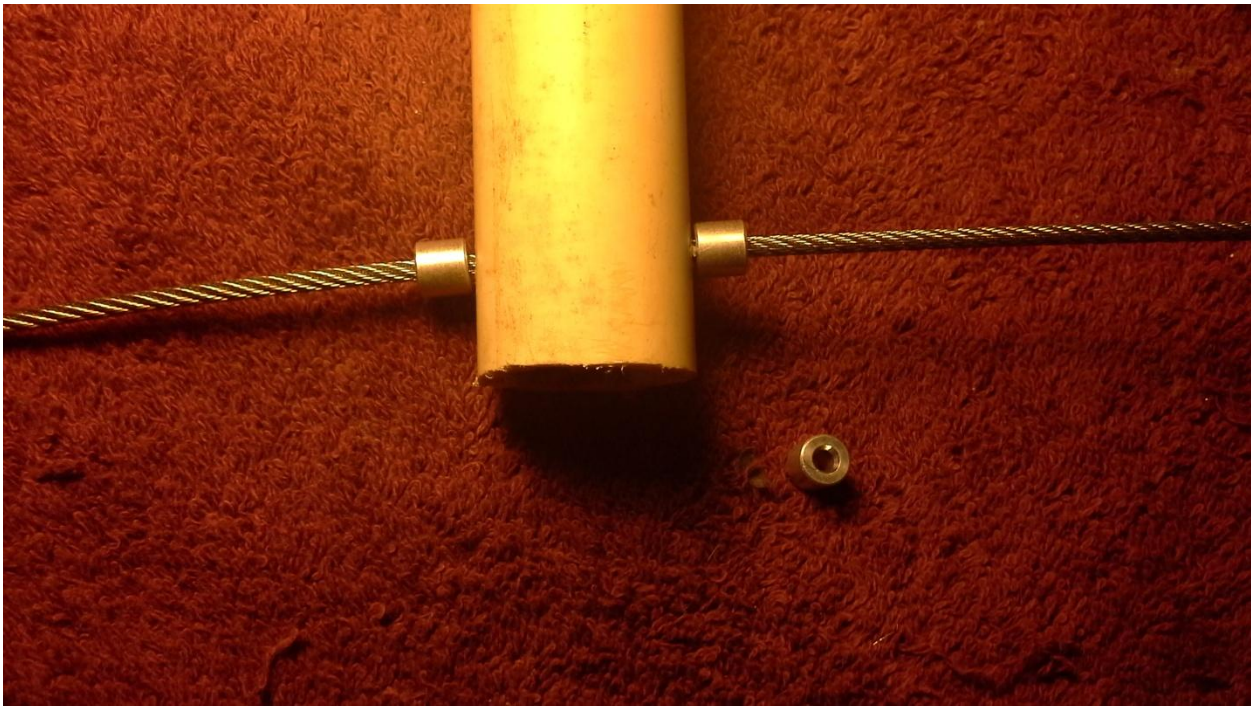
Use Tightly Wrapped Stiff Wire, Wire Ties or Small Hose Clamps to Secure the Center Brace



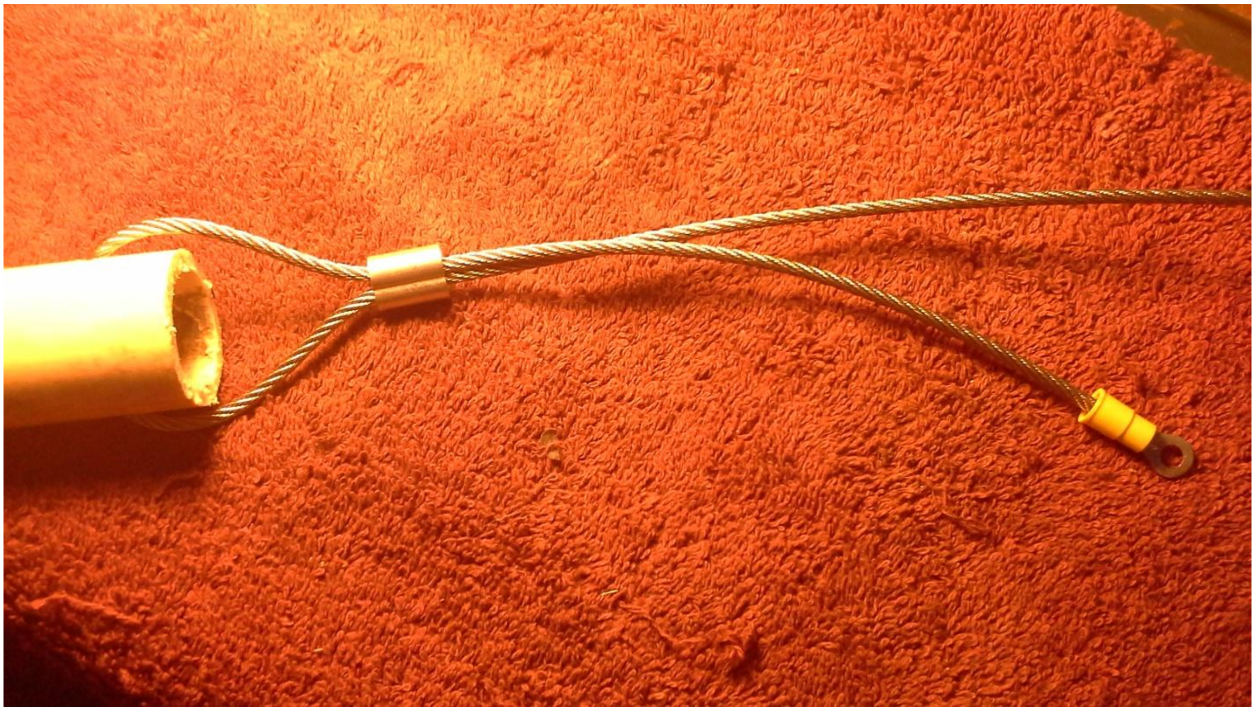
This is one way to make the three wire joint at the end insulator. Drill three sets of three holes around the pipe and thread the wire through as shown. Then solder the three wires together and tape. Tape over the end of the pipe where the wires thread through to help hold them in place.



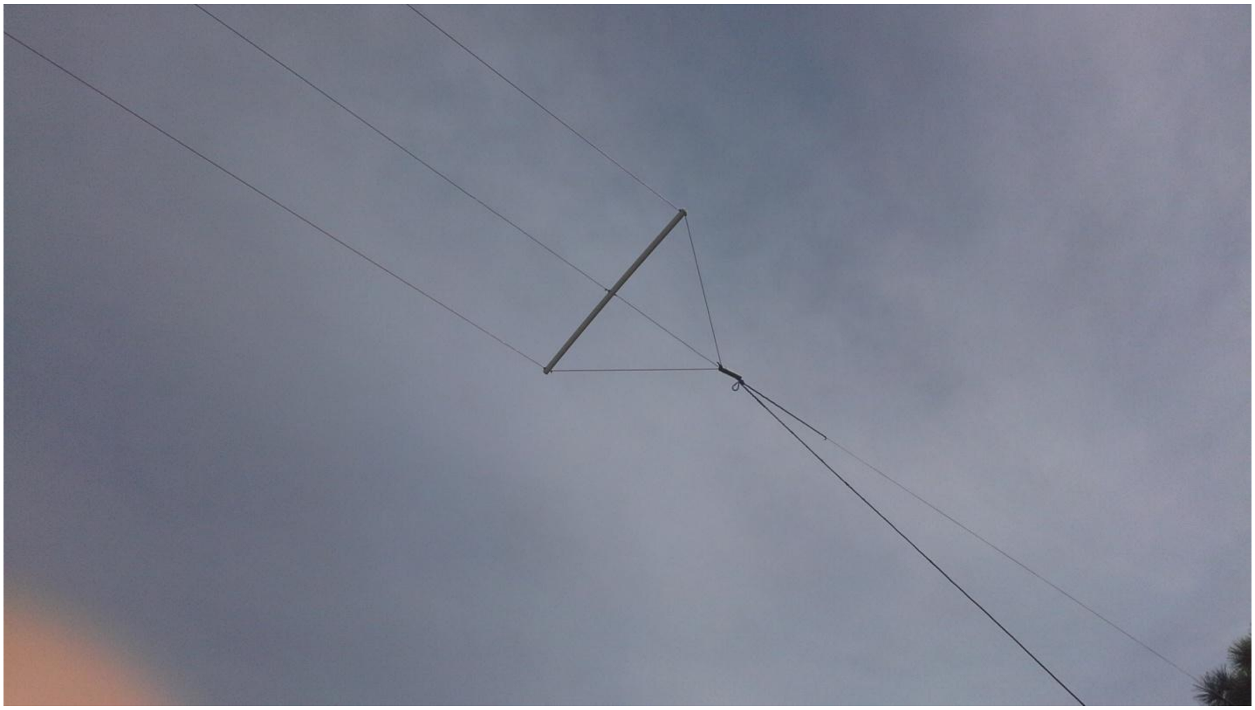
Another example of the end insulator apex connection using two cable clamps and end stops on the center lead. A larger ferrule or two would be better than the two clamps. The outer wire is one piece from the outer center insulator through the spreader, through the end insulator and back through the spreader to the other outer center insulator. Remember to slide on the ferrules as you go.



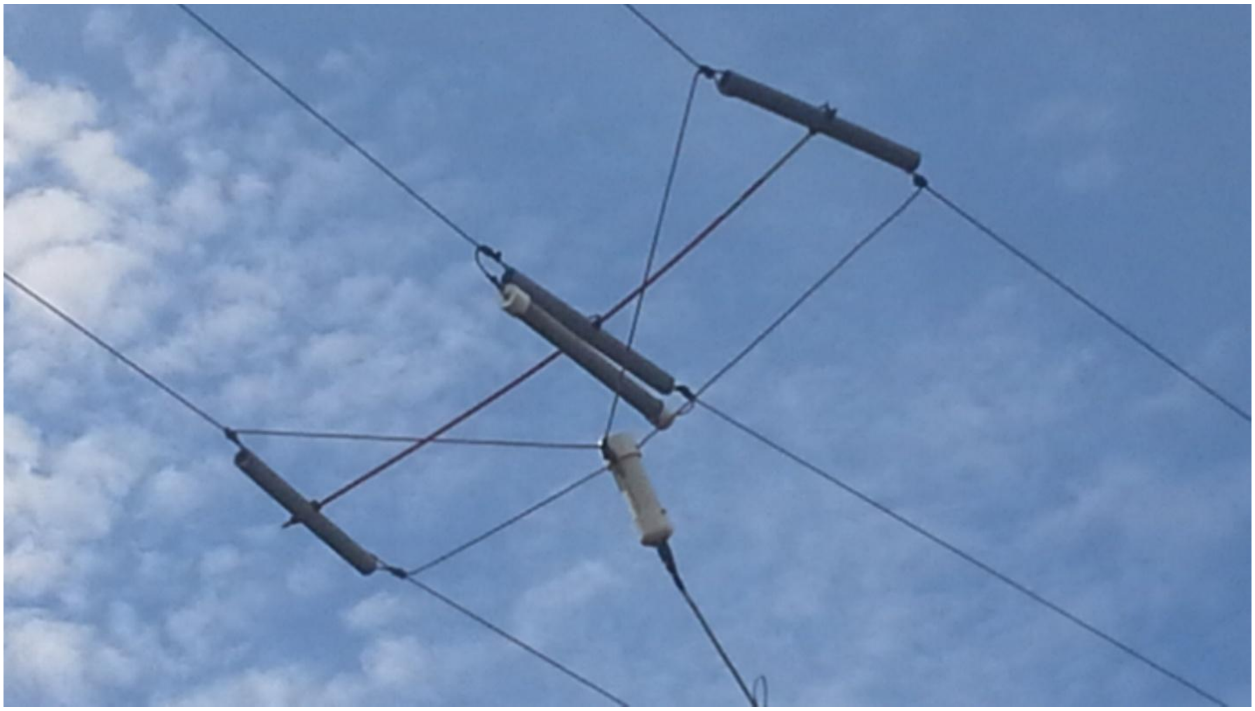
Use end stop ferrules to lock the spreader in place.



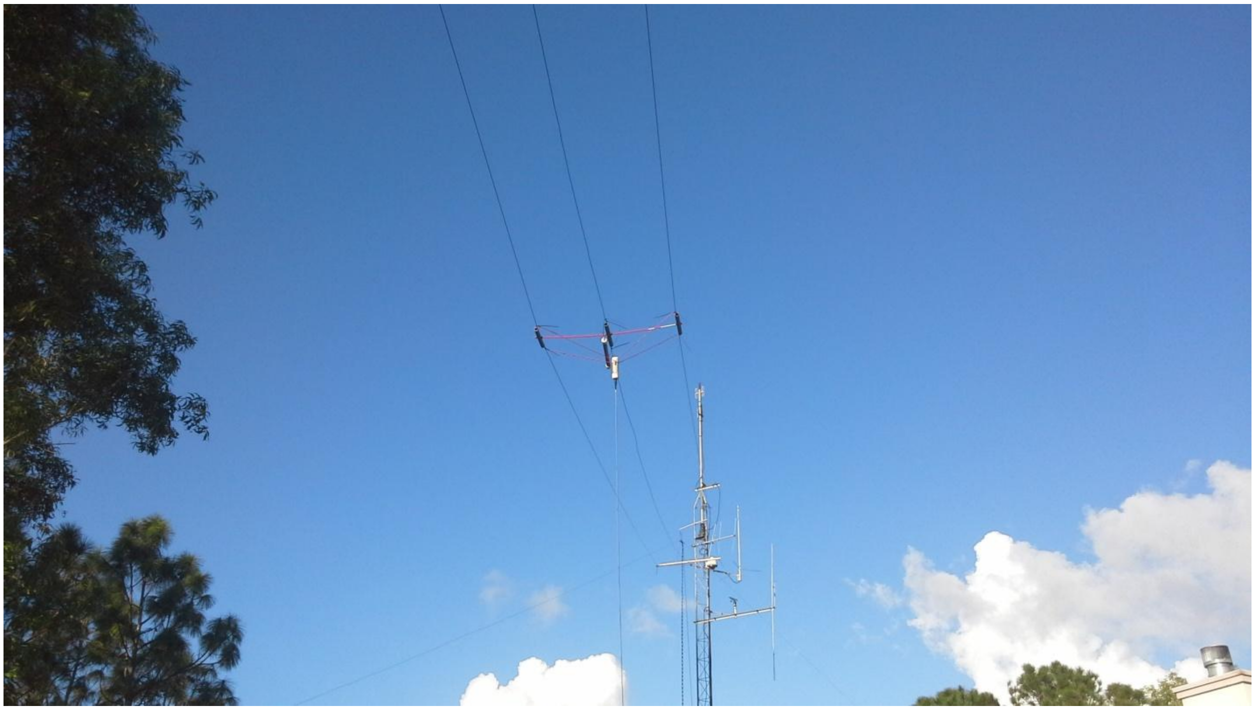
Here is an example of a connection tail. Use a ferrule to lock the wire in place and crimp the appropriate ring terminal on the end. Remember, the tails going to the Balun are at longer than what is shown. This is the tail going to the termination resistor.



Looking up at one of the 4 ft wide end spreaders and end insulator.



Here is a close up of the installed center section. The Termination Resistor is hanging below the center insulator and the Balun is hanging below that on the legs of the outer wires. The fiberglass rod center support is bending a bit from the stress of the coax weight and pull off center. A piece of aluminum tubing would be better.



Here is the installed view of theT3FD Antenna and other parts of the KA2UFO Aluminum Flying Circus. The 90FT version has only one spreader on each end, no intermediate spreaders except for center support.

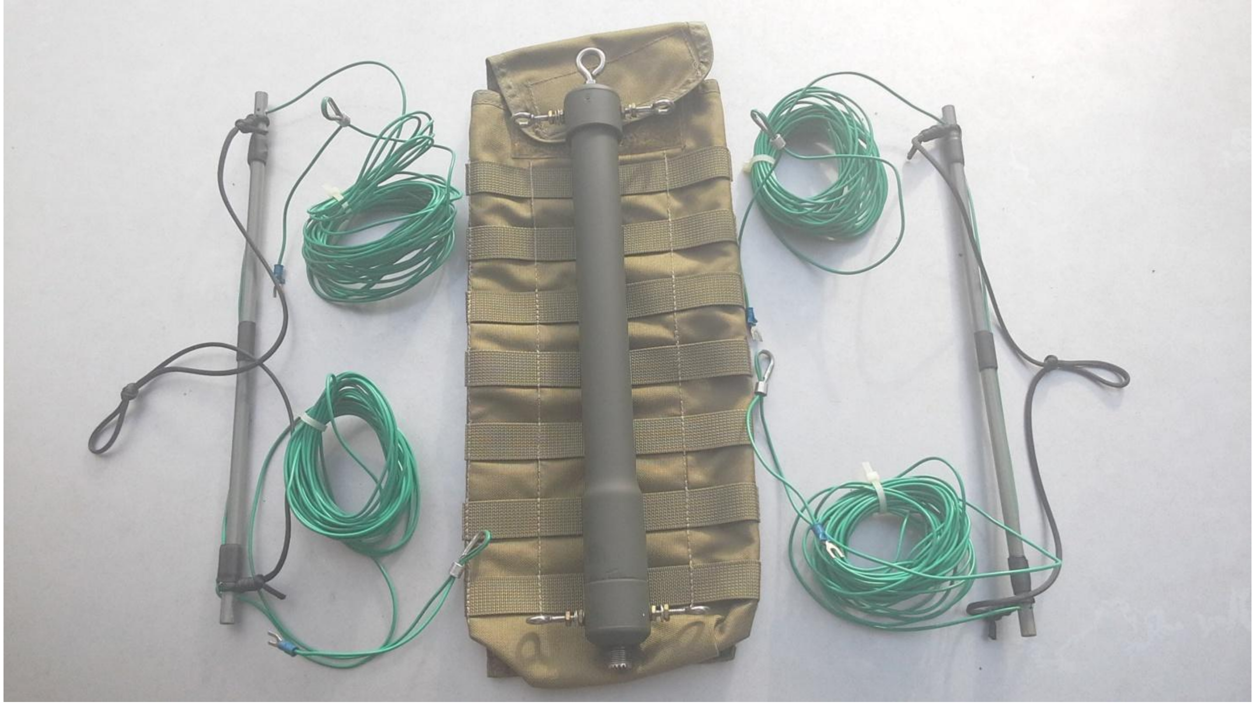
T3FD PERFORMANCE

Typical VSWR Measurements for the T3FD on the ALE HFN frequencies are shown in the table. The antenna ends are about 30 feet up with the center sagging down to about 25 feet. I've been using an ICOM M710 150W PEP radio with this antenna for ALE PC-ALE / ALE^STAT. For ALE, SelCal and WinLink I have been using a BARRETT 2050 125W PEP radio, so far no smoke ;=). Under current propagation conditions, Soundings are being heard throughout the US and at times into Europe. See the HFLink live map for more data, and the Cebik document for in depth information on design, efficiency etc.

BAND	VSWR
160M	1.2:1
80M	1.2:1
60M	1.5:1
40M	1.6:1
30M	1.3:1
20M	1.3:1
17M	1.3:1
15M	1.3:1
12M	1.1:1
10M	1.4:1

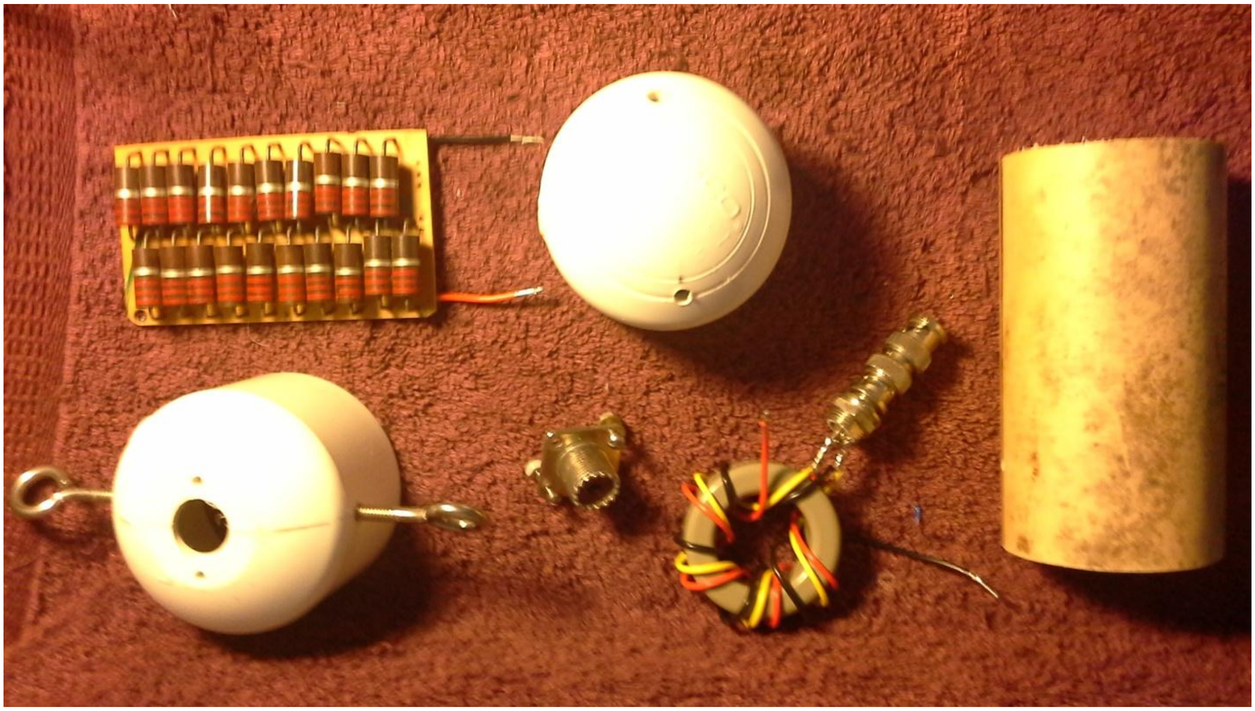
OTHER EXPERIMENTS AND IDEAS

Here is a Portable T2FD antenna which rolls up and fits in a hydration pack bag. This has the 4 core 9:1 Balun as the T3FD and a 40 Watt 900 Ohm Termination. Spreaders are 14 inches, overall length 60 ft. The center Termination Balun section is made from 1" electrical conduit with that nice flare on the end to fit the Balun cores. Not shown are tiny carabineer style clips to attach the wires to the eyebolts.

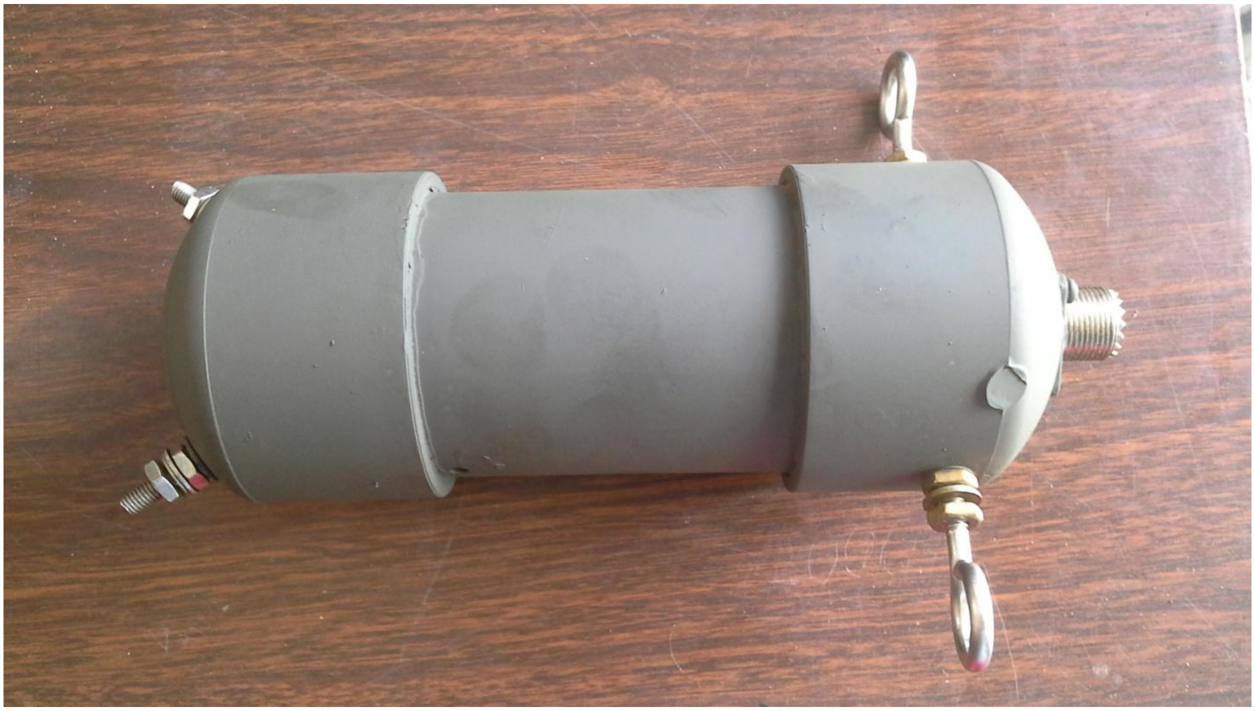


Portable T2FD Antenna fits in Hydration Bag. Spreaders are made from fiberglass tent poles.

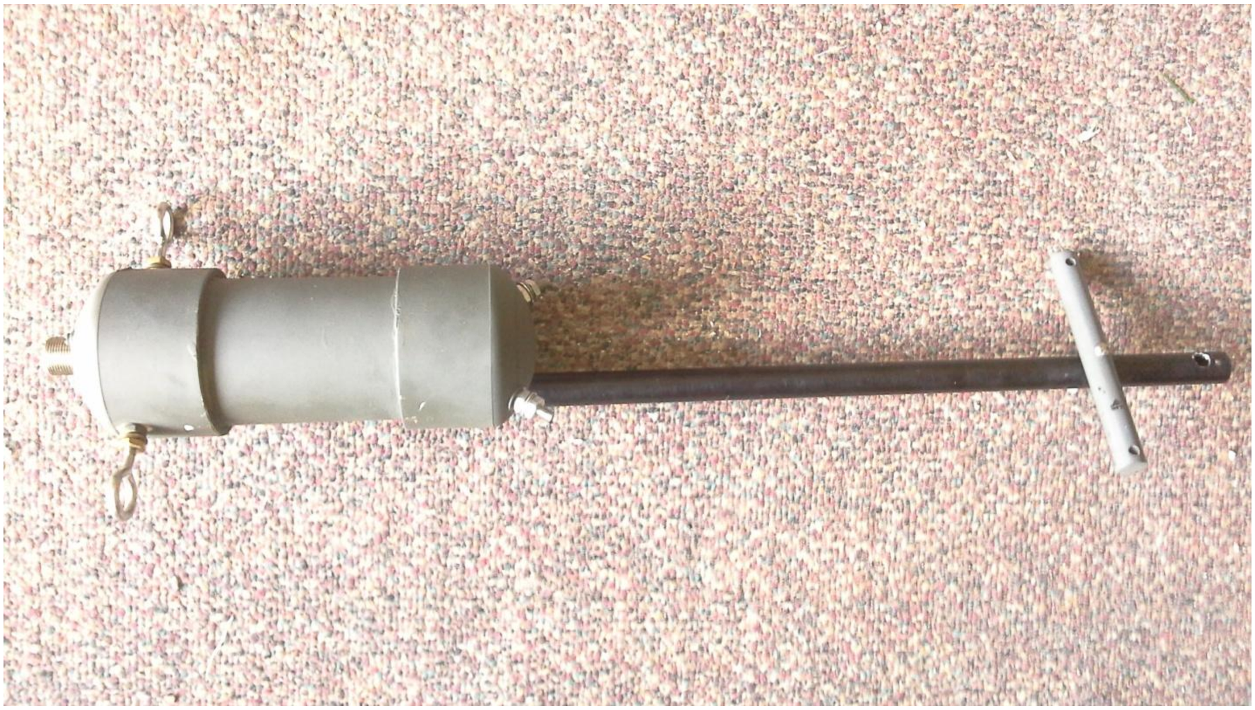
This is the first Termination and Balun setup I built for the 2 leg terminated dipole experiment. Both the core and termination resistors are in the same assembly. This setup would work nicely for the bowtie antennas with the correct Balun and termination value.



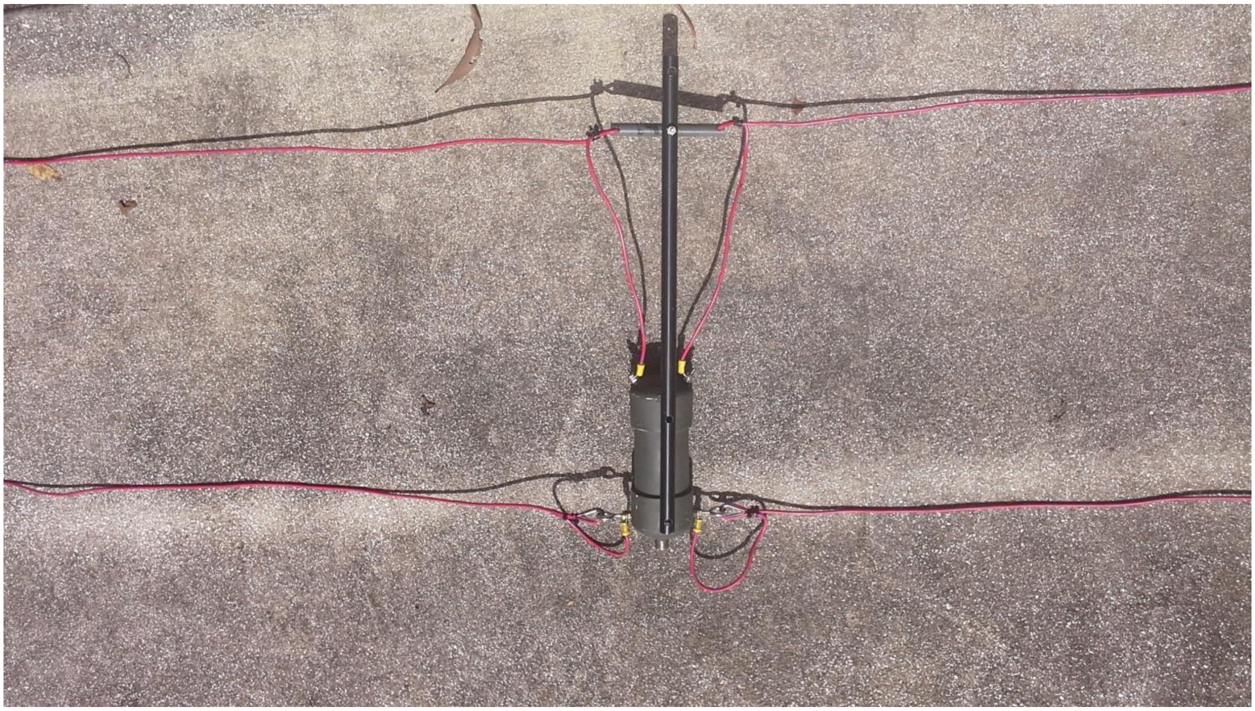
Beginnings of a 9:1 Balun and 450 Ohm Termination center assembly for 2 leg T2FD



Finished Balun Termination assembly. I learned not to glue things together!



Attached spreader and insulator to the Balun termination assembly



Center section for the T2FD antenna experiment. Spreaders are 18 inches.

REFERENCES

L. B. Cebik, Notes on Wide Band Multi Wire Folded Dipoles 4/3/2010

http://www.antentop.org/w4rnl.001/radio.html

http://www.cebik.com/content/a10/wire/wbmw.html

HFLINK site for BALUN instructions

Modified version of the KISS Balun by K6KBE uses 4 #31 ferrite cores, 16ga Teflon coated wire

http://www.HFLINK.com/Antenna

BUSHCOMM for the 3 leg commercial version

BBA 100 Series – 27 meter (89 FT) or 54 meter (177 Ft) long three leg terminated dipoles

https://www.bushcomm.com.au/brochurelibrary/DB00538R6%20-%20BBA%20HF%20Broadband%20dipole%20series%20Overview.pdf

BILL OF MAJOR MATERIALS

Part	**Source**	**Qty**	**Price ea**	**Price Extended**
PVC Pipe 1” x 10FT	Home Depot	2	$4.00	$8.00
PVC Pipe Cap 1”	Home Depot	2	$0.83	$1.66
PVC Pipe 1 ½” x 6”	Home Depot	1	$2.00	$2.00
PVC Pipe Cap 1 ½”	Home Depot	2	$1.14	$2.28
Reflective Rod 48 inch fiberglass rod	Home Depot Model# 848638	1	$1.99	$1.99
Stainless Screw #10 x24 x 1 ½ 3 per bag	Home Depot Model # 801571	2	$1.18	$2.36

	Internet #204596473 Store SKU #462738			
Stainless Nuts #10 x 24 aircraft nut 4 per bag	Home Depot Model # 800121 Internet #204274165 Store SKU #316908	2	$1.18	$2.36
Stainless Flat Washer #10 12 in a pack	Home Depot Model # 800331 Internet #204276461 Store SKU #369332	1	$1.18	$1.18
Stainless Sheet metal Screw #8 x 1/2 50 in pack	Home Depot Model # 802912 Internet #204275048 Store SKU #442305	1	$4.24	$4.24
Stainless Screw #4-40 x 1 ½ 5 in pack	Home Depot Model # 801701 Internet #204282633 Store SKU #493824	1	$1.18	$1.18
Stainless #4-40 nut 4 in pack	Home Depot Model # 08681 Internet #203436213 Store SKU #982441	1	$1.18	$1.18

Stainless Washer 12 in pack	Home Depot Model # 800311 Internet #204276459 Store SKU #380250	1	$1.18	$1.18
Ring Terminals12 - 10 AWG #8 - 10 Stud Size 15 in a pack	Home Depot Model # 15-106 Internet #202522865 Store SKU #431390	1	$2.62	$2.62
Ferrite Cores for Balun PACK OF 6 17.5 X 10 X 28MM Ferrite Cores	AMAZON AEXIT T1712144065 ASIN: B07BWC5ZDR	1	$12.76	$12.76
Teflon Coated #16 Wire for Balun Solid Blue PTFE, stranded 19/29, 300v, 150ºC, 0.015" Mfg: Rubadue	Surplus Sales of Nebraska (WTF)UL1199BK16	4	$0.55	$2.20
Metal Oxide Film Resistors 10 in pack 220 Ohm 5 Watt Need 2 packs	AMAZON Electronics Salon	2	$9.49	$18.98
SO-239 Connector	Junk Box!	1		$5.00
Toughcoat 'Silky' 13 AWG, 19 strand 40% copper-clad steel (OD 0.0795") with tough, high density, low-gloss polyethylene (Nominal OD, 0.120" including 0.020" jacket. Break strength 400lbs PN 531	The Wireman	300	$0.35	$105.00
APPROXIMATE TOTAL COST w/o Tax or shipping	**90ft T3FD**			**$177.00**

Teflon Coated Wire for Balun (and those big ceramic insulators!)

http://www.surplussales.com/wire-cable/Wire4.html

Antenna wire

https://thewireman.com/antennap.html

A Lower cost alternative for the antenna wire

543	FLEXWEAVE™ 12 AWG, 259 strand bare copper ultra-flexible antenna wire, for heavier applications. Break strength 170 lbs.	300	0.28	$84

Yet another idea to save money is to use the 13 gauge Silky wire for the center wire. You can set up the alignment so that all the tension is on that center wire which has a 400lb breaking strength and use #12 insulated wire or other cheaper wire for the outer wires.

CONCLUSION

I hope this helps you build a T3FD antenna and have some fun with ALE. If you have any comments or suggestions, please let me know. Your mileage may vary. Tony KA2UFO@comcast.net West Palm Beach, Florida.

BBA-1kDE-X Extreme Conditions HF Antenna

- **HF BROADBAND MULTIWIRE ANTENNA**
- **2.0kW PEP - 1kW Continuous Data/Broadcast**
- **Strengthened for harsh Wind, Ice & Arctic environments**

The BBA range of broadband/wideband antennas are specifically engineered to meet the exacting standards required by commercial, government & Military operators.

The Bushcomm BBA has the flexibility to be installed in either a horizontal or sloping linear configuration or in an inverted 'V' format.

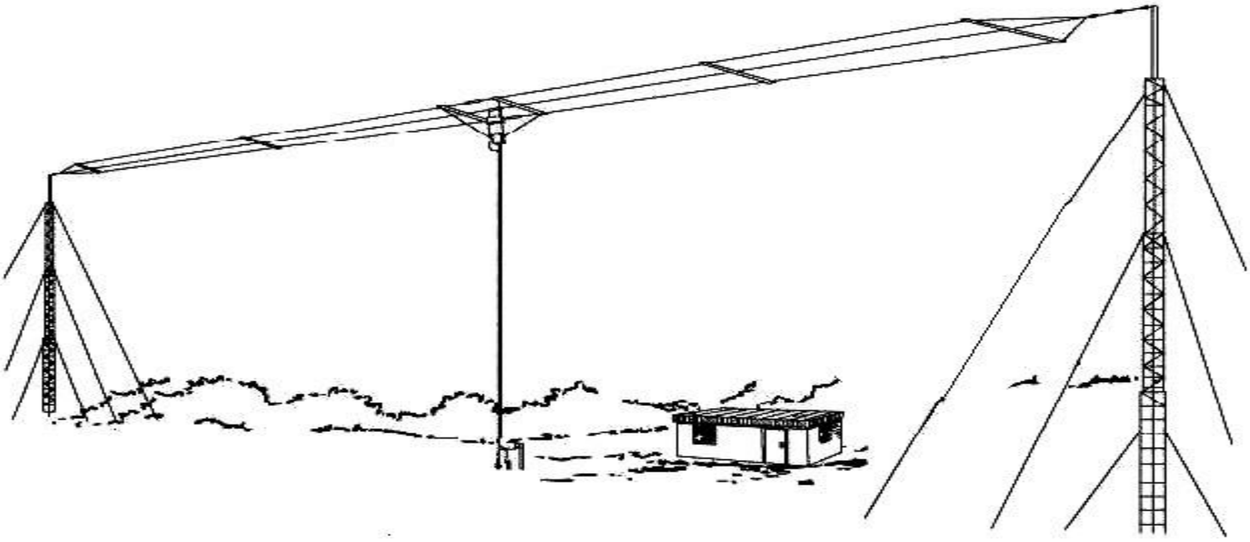
The standard **BBA-1kDE** 's light, yet sturdy construction ensures low total mass wind loading. The highest quality materials are used in construction. Stainless steel wire and fittings and UV resistant fibreglass rods, produce an antenna that will survive the rigours of the outdoors for many years.

SPECIAL FEATURES

- 1.6-30 MHz with VSWR < 2:1 (Typ.)
- No tuner required
- S/S wire and fittings
- UV resistant rod & balun/load boxes
- Easy installation (instruction provided)
- Configurable in horizontal or inverted V
- Suitable for continuous data
- Strengthened for harsh conditions

The **BBA-1kDE-X** variant employs custom manufactured low ice retention spreader rods and insulators to withstand extreme wind and snow-ice conditions. It uses 3.2mm stainless steel wire elements.

CE RoHS



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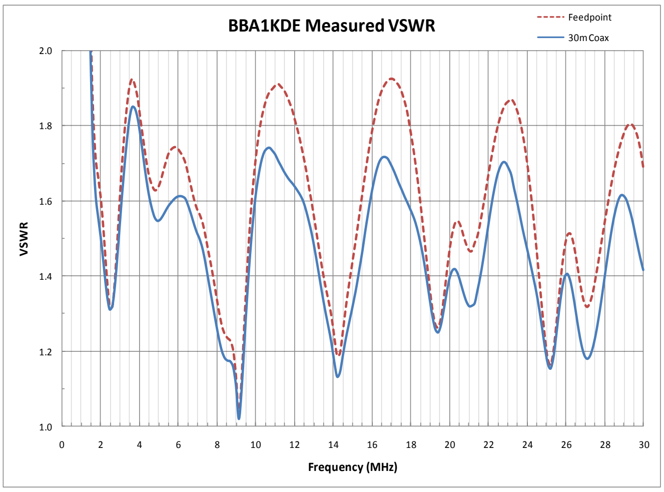
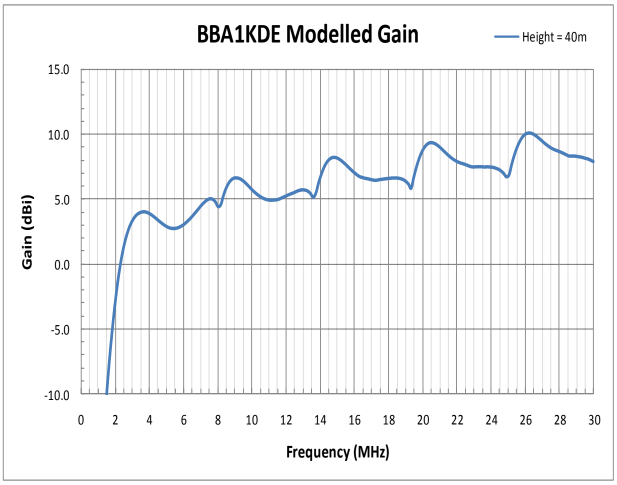
Specification Summary

SPECIFICATION	
ELECTRICAL	
Frequency Range	1.6 - 30MHz
Nominal Input Impedance	50 Ohm
VSWR	Typically < 2.0:1 (30m RG58 feeder)
Gain (height dependent)	5dBi (typical) -5dBi at 1.8MHz (typical, 40m height)
Power Rating	1kW Continuous (2.0kW PEP)
Input connector	UHF Type socket (S0239)
MECHANICAL	
Operating Temperature	-40°C to +50°C
Storage Temperature	-40°C to +85°C
Ice Loading	0.6cm , with reduced wind loading
Shipping	1500x380x170 mm, approx 19.5kg
Antenna Length	54 metre
Radiating elements	3.2mm Stainless Steel (304)
Wind Rating	210 km/hr*
Mast Spacing	58m horizontal tower spacing**, 40m footprint Inverted V

Above: Bushcomm Balun showing pigtail strain relief feature***

* In accordance with AS1170.2 – 1989 SAA Loading Code – Wind Loads
** Approximate spacing. Will vary location to location and depending on preference
*** Coaxial cable not included, can be purchased separately





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BBA - 100CS HF ANTENNA

HF BROADBAND MULTIWIRE DIPOLE
COMPACT

Our flagship model and all-round best performer is the BBA series of high power base station antenna systems.

Engineered to the exacting standards required for professional applications, the comparatively affordable BBA series antennas are used by private, commercial, government, and tactical HF system operators worldwide.

The Bushcomm BBA is also adaptable enough to suit various physical installation requirements. Between two purpose built towers at a professional site, between trees or other structures, and even in an inverted “V” configuration to suit NVIS applications *.

Light yet sturdy construction ensures low total mass wind loading. The highest quality materials are used in construction, such as stainless steel radiating elements and UV resistant fibreglass rods. This produces an antenna that will survive even the harshest of outdoor environmental rigours for many years.

There are many variants in the BBA family with sizes and power ratings to suit a wide range of applications.

DR DIGITAL HF VOICE & DATA RADIO COMPATIBLE

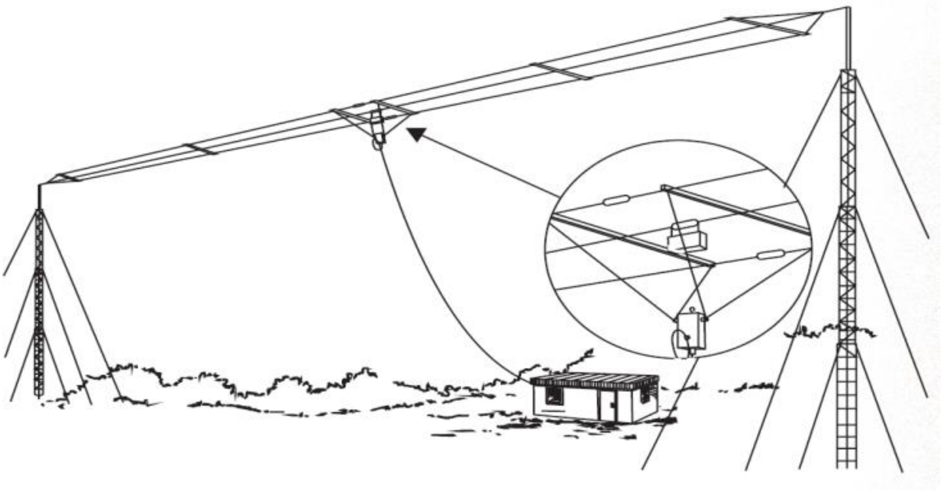
FULL BBA SERIES FAMILY:

* BBA100V - 125w, 2.0~30Mhz, 27M
* BBA100C - 250w, 2.0~30Mhz, 27M
* BBA100CS - 250w, 3.0~30Mhz, 20M
* BBA100CE - 250w, 1.6~30Mhz, 54M
* BBA-600VS - 600w, 3.0~30Mhz, 20M
* BBA600V - 600w, 2.0~30Mhz, 27M
* BBA600VE - 600w, 1.6~30Mhz, 54M
* BBA1kD - 2kW, 2.0~30Mhz, 27M
* BBA1kDE - 2.5kW, 1.6~30Mhz, 54M
* BBA1kCF - 2.5kW, 1.5~30Mhz, 74M

SPECIAL FEATURES

- 3.0-30mhz
- NO TUNER REQUIRED
- S/S Wire and Fittings
- UV Resistant rod & balun/load boxes
- Easy Installation (instruction provided)
- Variation of length and power available
- Configurable in Horizontal or Inverted V
-
- Suitable for continuous data

CE RoHS



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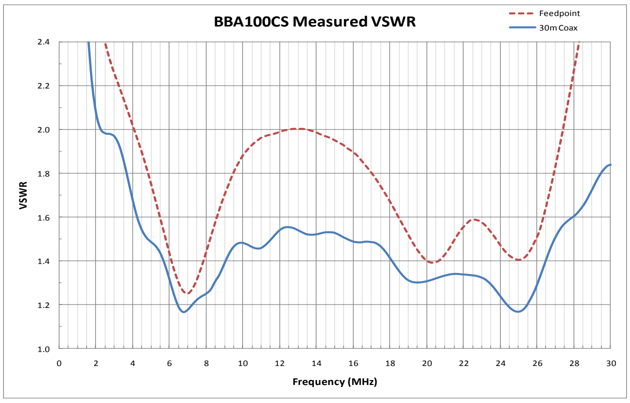
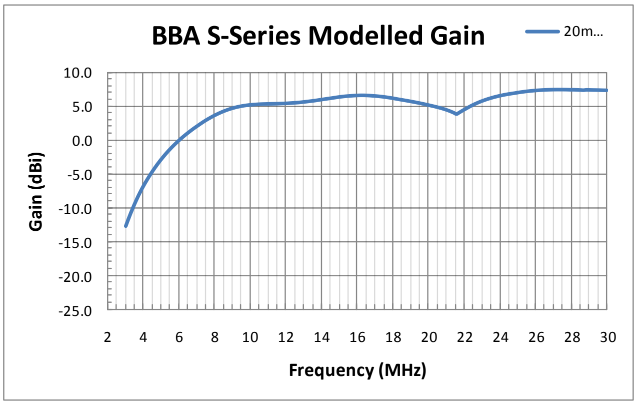
Specification Summary

SPECIFICATION	
ELECTRICAL	
Frequency Range	3.0 - 30MHz
Nominal Input Impedance	50 Ohm
VSWR (typical)	Better than 2:1 (30m RG58)
Gain	5dBi (typical) -6dBi at 4.9 MHz (typical)
Power Rating:	130W continuous. 250W PEP (voice)
Input connector:	UHF Type socket (S0239)
MECHANICAL	
Operating Temperature	-30°C to +50°C
Storage Temperature	-40°C to +85°C
Ice Loading	0.6cm , with reduced wind loading
Shipping Weight:	Approx 4kg
Antenna Length	20 metre
Radiating elements	2mm Stainless Steel (G304)
Wind Rating	210 km/hr**
Mast Spacing	21m horizontal; tower spacing, 15m footprint Inverted V ***

Above: Bushcomm Balun showing coaxial strain relief feature****

* Recommended Mast Height - 10m minimum
** In accordance with AS1170.2 – 1989 SAA Loading Code – Wind Loads
*** Approximate spacing. Will vary location to location and depending on preference
**** Coaxial cable not included, can be purchased separately





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Bushcomm HF ANTENNA MANUFACTURER

OFO - OPEN WIRE FEEDER OPTION

NVIS KIT FOR BBA SERIES HF ANTENNAS

Want to enhance lower frequency reception on your antenna? Have a look at our OFO KIT.

Designed to complement our BBA (multi-wire) models and similar antennas, the OFO NVIS kit is easily constructed and attached to your existing multi-wire or can be purchased in conjunction with one of our antennas

Lightweight with low visual impact, the OFO KIT when assembled measures just over 10m in length as standard. Custom lengths can be also be supplied to to suit the end users requirements.

The OFO is constructed with lightweight but extremely durable composite material spacers with snap-lock wire holders as well as quality stainless steel wire & fittings.

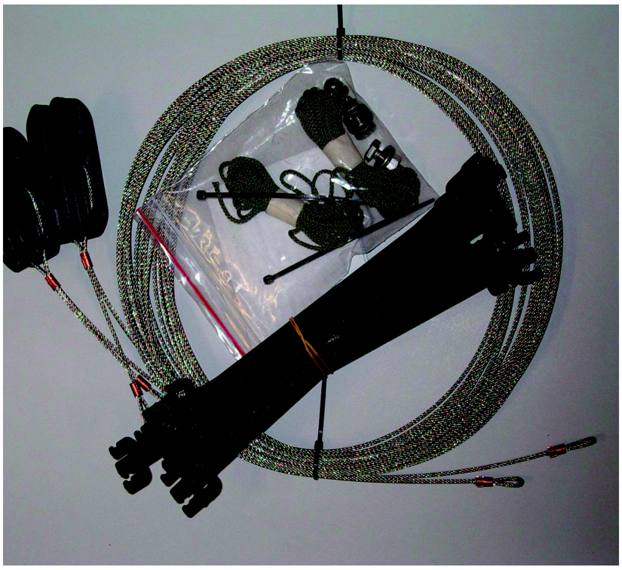
The OFO is a complete kit of most things necessary to install it yourself.

Note: Stand alone OFO Kit Suits BBA-100 series antennas when used in a horizontal configuration only. Optional balun cradle mount will be required for inverted Vee installations.

Not compatible with BBA-600 or BBA-1Kxx series antennas

SPECIAL FEATURES

- Improved Performance on Lower Frequencies - Short Path NVIS
- Can be made to various lengths
- S/Steel wire



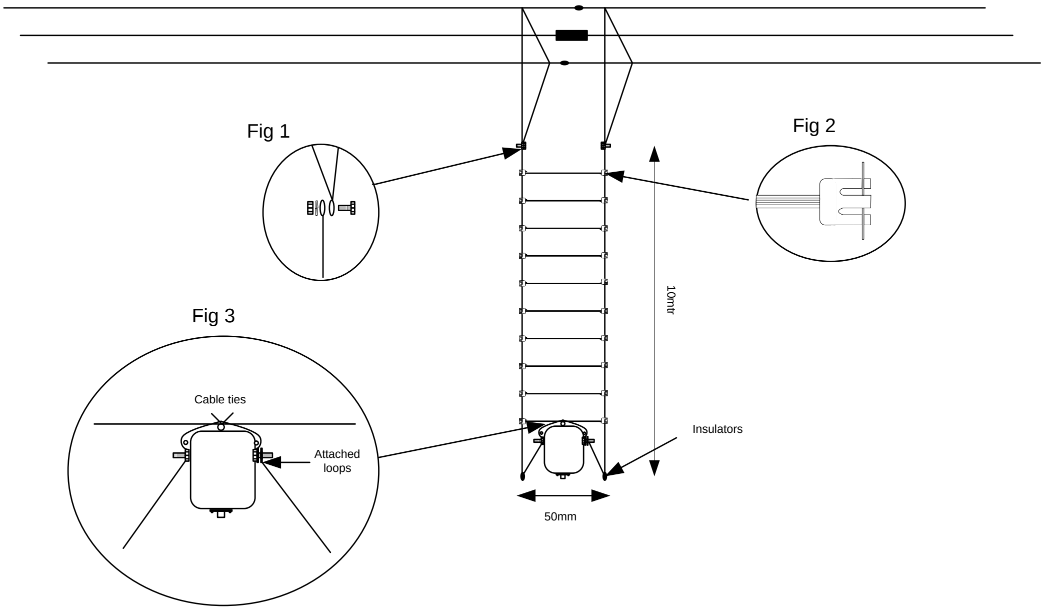
Installation Kit Contents:

- 2 S/Steel nuts
- 2 x 10m S/Steel wire (loops fitted)
- 2 x S/Steel Bolts
- 2 x S/Steel Washers
- 6m cord (2 x 3m)
- 10 x Special Wire Snap-Lock Spacers
- Instructions
- Extra ferrules (incase of length adjustment)

MECHANICAL

Shipping Weight:

800grams **Length:** 10m standard



Basic installation guide

FOR FURTHER INFORMATION

VISIT OUR WEBSITE!!:
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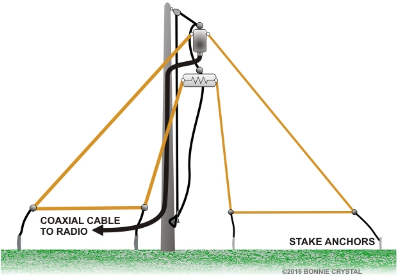
FAX: +61 8 9378 4429

DEALER STAMP

Broadband Butterfly Terminated Dipole Antenna (BBTD)

Inverted V Pyramid Configuration with a flagpole support (perspective view from side)

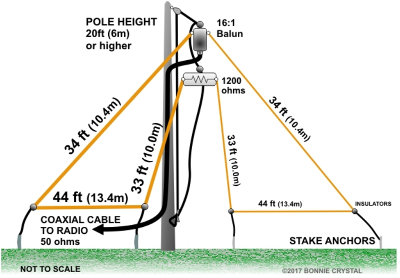


Broadband Butterfly
Terminated Dipole Antenna (BBTD)

Inverted V Pyramid Configuration
with a flagpole support
(perspective view from side)

Dimensions Optimized for 7 MHz ~ 54 MHz

with < 2:1 SWR 1.8 MHz ~ 54 MHz - TUNER NOT NEEDED

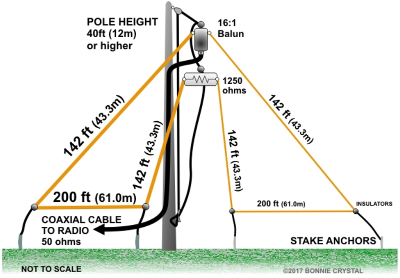


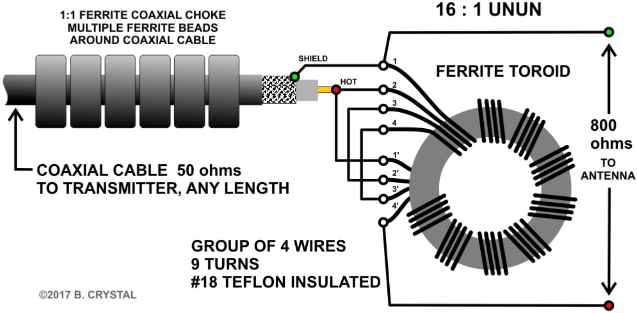
Broadband Butterfly
Terminated Dipole Antenna (BBTD)

Inverted V Pyramid Configuration
with a flagpole support
(perspective view from side)

Dimensions Optimized for 1.8 MHz ~ 30 MHz

with < 2:1 SWR 1.5 MHz ~ 30 MHz - TUNER NOT NEEDED





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Chapter 2
Cold Weather Effects and Operational Considerations

2-1. General

Cold weather operations are a necessary part of doing business in Alaska. With the proper equipment preparation and training, Soldiers can fight and win on the Arctic battlefield by following guidelines set forth in this regulation.

2-2. Personnel

Self-preservation consumes a large portion of every Soldier's time and energy while operating in cold weather. This reduces personnel efficiency in equipment operation and maintenance. In addition to operating and maintaining equipment, Soldiers and leaders must learn what is appropriate and how to adjust when operating in an Arctic environment. As the temperature decreases, all routine tasks will increase from simple to maximum effort required. It cannot be overstated that at temperatures below -50° F, simple tasks require maximum effort of well-trained personnel on completely winterized equipment.

2-3. Cold Weather Materiel Utility

Before acquisition, much of the Army's equipment is developed and tested for proper cold weather operation at temperatures down to -25° F. Almost all equipment procured by the Army functions correctly at the -25° F threshold. At temperatures below -25° F, equipment begins to malfunction exponentially corresponding directly with decrease in temperature. Current efforts at Army level are addressing acquisition processes to ensure that equipment fielded for operation in extreme cold temperatures meets requirements of -25° to -60° F. Most TMs currently outline special operating procedures for cold temperature operations, but many do not address specific operating procedures and maintenance requirements for the extreme cold temperatures. Failure to follow the "Operations Under Unusual Conditions (Cold)" procedures in the operator and field maintenance TMs and guidance in this regulation will result in unit financial and readiness impacts from equipment failures in cold and extreme cold temperatures.

2-4. Cold Effects on Materiel

a. Metals. Metals become brittle in severe cold temperatures and parts cannot withstand the same shock loads that they sustain at higher temperatures. At -20° F certain steels can only withstand 50 percent of the shock load that they can withstand at room temperature. For a given change in temperature, various metals will expand or contract different amounts. These characteristics will especially affect bearings in which the bearing and shaft are of different metals, parts of different type metals bolted together, and meshing gears of different metals. Take special care in adjusting these types of parts for cold weather operations, especially when adjusting bearing clearances.

b. Rubber. In addition to natural and synthetic rubber, there are many rubber substitutes. These synthetic rubbers look and usually react like natural rubber, and mostly retain flexibility at high temperatures. As it cools, natural rubber will gradually stiffen and begin to exhibit peculiarities below -20° F. When cooled gradually but continuously over a short time, the rubber will remain flexible until reaching approximate -60° F. At this point, the rubber suddenly loses elasticity and becomes brittle. Furthermore, if the rubber is consistently kept at a temperature below -20° F for a long time, an effect similar to crystallization occurs, causing it to become brittle.

c. Rubber covered cables. Take extreme care in handling electrical cables at low temperatures. If the rubber jackets become hard, protect the cables from shock loads and bending to prevent short circuits caused by any covering breaks. Neoprene jackets on cables become very brittle and break easily at low temperatures.

d. Tires. Tires become rigid in the cold, causing flat spots on the portions that touch the ground during shutdown periods. Sidewalls become brittle and crack in severe cold temperatures. Tread surface properties will vary depending on the rubber used in the manufacturing process, but will lose "gripping" properties on ice as temperatures decrease and the rubber stiffens. Inflate tires to appropriate pressure in cold temperatures. A tire inflated to 40 pounds Per Square Inch (PSI) indoors will change to 25 pounds PSI when moved outside at -50° F. Generally, inflate room temperature tires to 10 pounds PSI over the normal pressure during cold weather, and recheck tire pressure before operations.

e. Plastics. Generally, plastics expand and contract much more than metal or glass. Handle any plastic parts or materials carefully. Many vehicular canvas covers have plastic windows that become very brittle and, in many cases, break due to a combination of cold and vibration.

f. Glass. If handled carefully, expect glass, porcelain, and other ceramics to perform normally at low temperatures. If applying heat directly to cold windshields or vehicle glass, cracking may result.

g. Fabrics. Kept dry, fabrics generally retain their flexibility even at extremely low temperatures. However, tarpaulins present difficulties in conforming to their intended.

dimensions due to shrinkage. This is usually the result of wrinkles that are extremely difficult to smooth out at subzero temperatures. Whenever possible, unfold tarpaulins in heated enclosures

h. Liquids. Place special training and emphasis on keeping water and other liquids in a liquid state. Proper attention must be paid to freeze protection properties and additives for engine coolant, windshield washer fluid, etc. Items containing liquids susceptible to freezing in extreme cold temperatures, such as batteries and Petroleum, Oils, and Lubricants (POL), must have warm storage or thawing equipment available before use.

i. Batteries.

(1) Vehicle batteries. Vehicle batteries lose their effectiveness during extreme cold weather operations and will freeze if not maintained at a full state of charge. Most USARAK vehicles have been outfitted with Valve Regulated Lead Acid - Absorbed Glass Mat (VRLA-AGM) batteries, which provide better potential to recover/recharge if properly thawed before servicing. Cold chamber testing has revealed that a fully charged battery can withstand temperatures of -70° F without freezing. Conversely, a fully discharged battery can freeze at 10° F. If a standard flooded-cell vehicle battery is not maintained at full charge, the internal cells may sustain permanent damage from expansion of the frozen electrolyte. Never jump (slave start) a vehicle with frozen batteries, or they could explode. Specific cold chamber testing is being conducted for VRLA-AGM batteries as of the release of this Regulation, Table 2-1 shows how much of a flooded-cell lead acid battery's power is lost as the temperature drops.

Table 2-1 Flooded-Cell Vehicle Battery Efficiency

Efficiency Percent	**Temperature**
100%	Room Temperature (77 Degrees Fahrenheit)
50%	15 Degrees Fahrenheit
30%	-20 Degrees Fahrenheit
10%	-30 Degrees Fahrenheit

(2) Small equipment batteries. For small equipment, alkaline batteries are far superior to carbon batteries. For example, a flashlight using "D" batteries should use the BA3030/U rather than the BA-30. Also use these batteries in artillery and mortar night aiming post lights and tactical telephones such as the TA 312/PT. While dismounted, Soldiers should keep spare small equipment batteries in interior pockets to help keep them warm.

(3) Lithium sulfur dioxide batteries. The lithium sulfur dioxide battery is recommended for use in extreme cold conditions. Lithium sulfur dioxide batteries have unique characteristics that provide improved operational capabilities and extended battery life. Handle lithium sulfur dioxide batteries as hazardous material when new and during use, and dispose of them as hazardous waste when depleted. Refer to TB 43-0134 for disposition procedures.

2-5. Maintenance Planning

The importance of Preventive Maintenance Checks and Services (PMCS) and equipment repair planning become paramount in Arctic conditions. Man-hour requirements for operators and maintainers to complete all tasks must be considered when planning and executing maintenance operations in extreme cold temperatures, periods of heavy snowfall, and extended hours of darkness. At temperatures below -20° F, maintenance tasks could require up to five times the normal amount of time to complete. The additional time resourced to increase the frequency of equipment PMCS tasks must be considered while planning operations during winter months in the Arctic. Complete equipment winterization, diligent maintenance programs, and well-trained crews are the keys to effective cold weather operations. Several factors that affect maintenance directly and require detailed planning are:

a. Appropriate facilities or maintenance shelters are necessary to provide a protected workspace for personnel to operate in reasonably comfortable temperatures. Whether the structure is a permanent building in garrison or a maintenance tent in field environments, appropriate heaters must be available to warm the workspace and equipment requiring maintenance. All planning should include accommodations to bring equipment inside which require extensive or precise inspection/work, well in advance to melt snow and/or ice and warm components before conducting maintenance. Lighting should be sufficient to provide visibility necessary to conduct maintenance, to include undercarriage work. Lighting becomes a critical planning factor in Arctic regions during winter months when natural daylight hours are significantly reduced. If operating in a field environment, ensure planning includes appropriate measures to clear ground snow and/or provide insulating material to place on the ground to prevent operators/mechanics from lying directly on the ground while working under vehicles. Rapid body cooling caused by heat transfer to the ground may result in cold weather injury. Additional considerations should include canvas or cardboard under vehicles to catch dropped parts. This prevents parts and fasteners from becoming lost in the snow. Leader involvement with maintenance operations in extreme cold weather is required to ensure that Soldiers do not operate equipment inside a building/tent without appropriate ventilation to prevent carbon monoxide poisoning.

b. Appropriate and sufficient Class IX repair parts and Class III POL should be managed to sustain equipment through the winter months. Many of the repair parts and POL products used throughout USARAK for winterized equipment are peculiar in nature, and often difficult to obtain on short notice. Proper planning for requisition, storage, and issue of these supplies before winter months will alleviate difficult sustainment challenges during extreme cold temperatures.

c. Proper planning for maintenance Soldiers' clothing and work performance is critical to timely repairs and service procedures. Extreme Cold Weather System (ECWS) gear issued to Soldiers in USARAK is often bulky and loose fitting by design, and not conducive or safe for performance of certain maintenance tasks. Leaders must ensure that Soldiers are appropriately dressed for extreme cold temperatures to prevent cold weather injuries, yet not working around moving shafts, pulleys, belts, fans, etc. with large gloves or loose fitting parkas that may get caught and cause injury. Gloves may become saturated with fluids when performing maintenance on fuel or cooling systems, which reduces the insulating value and may result in cold weather injury. Extreme cold weather fuel handler gloves will prevent fluids from contacting the skin, and if necessary the wear of rubber gloves under insulated gloves will prevent coolant and other liquids from contacting the skin. Never allow unprotected hands/skin to come in contact with cold metal.

Chapter 3
Equipment Winterization

3-1. General

Equipment fielded to USARAK units should arrive in Alaska fully winterized. As of the release of this regulation, significant requirements are being addressed at DA level to incorporate equipment winterization in AR 750-1 and Program Manager equipment fielding plans. Winterized equipment will include the application/installation of approved auxiliary arctic kits or equipment necessary to pre-heat and start equipment within one hour, maintain a temperature of 41° F in troop compartments, and ensure water remains in a liquid state (water buffalo) when in extreme cold temperature range of -25° to -60° F. The use of arctic grade lubricants and fluids for engines, transmissions, gear cases, hydraulic systems, and other assemblies as necessary should meet requirements outlined in USARAK Regulation 750-4 until such time that Army Lubrication Orders (Los) and TM are updated to reflect extreme cold climate operational requirements. All USARAK equipment winterization will be standardized as much as specific model design permits, regardless of the units' garrison location. Initial winterization of equipment currently owned by USARAK units that do not have approved auxiliary arctic kits in the equipment TM, will be coordinated by the USARAK G4, Maintenance Management Division until policies are finalized at DA level to require winterization prior to equipment fielding in Alaska.

3-2. Winterization Items

a. Liquid cooled, engine driven equipment will have the following devices installed:

(1) Engine block heater. This device is a permanently installed 120 volt Alternating Current (AC) electrical heating element that draws no more than 15 amps. It will be capable of maintaining engine coolant temperature at 80° F above ambient air temperature. Tactical generators with fuel-fired coolant preheaters do not require block heaters.

(2) Fuel-fired engine preheater. This device is a permanently installed engine coolant heater capable of heating and circulating coolant throughout the engine. It is electrically powered by the vehicle 24 volt Direct Current (DC) batteries, and draws fuel supply from the vehicle fuel system. At temperatures down to -60° F, the preheater will be capable of sufficiently heating an engine to start up temperatures in one hour or less.

(3) Battery maintainer. This device is a permanently installed 120 volt AC electrical maintainer that remains connected to the vehicle batteries at all times. This device will

draw no more than 5 amps, and provide sufficient trickle charge to maintain serviceable vehicle batteries (AGM or flooded-cell) in a full state of charge to temperatures of -60° F.

(4) Each electrical device will have an electrical cord with a polarity protected, grounded male connector. Multiple electrical devices will be connected through a "pig-tail" arctic-grade (remains flexible in extreme cold) cord with at least 14 gauge wiring, so that only one connector (120 volt AC, polarity protected, grounded, male) will extend from the vehicle.

b. Tactical vehicles designated to transport Soldiers shall be fitted with arctic hardtop kits that provide improved cabin area shelter and insulation. The hardtops are capable of withstanding heavy snow load and prevent rain and snow melt from entering the vehicle. The hardtop kits for troop carrier vehicles are designed to permanently install personnel heaters necessary to maintain troop cabin areas at 41° F (MIL-STD-1472G) in extreme cold conditions. Deliberate decisions must be made by commanders to determine operational requirements for troop transport with tactical vehicles. Although removable, the hardtops should remain on the vehicle once installed. Cargo areas for vehicles with hardtops are limited to access by the rear doors, and the equipment cannot be air-dropped during airborne operations with the hardtop installed.

c. Personnel heaters. Generally, tactical and combat vehicles provide adequate heat through standard engine coolant heaters during cold weather operations. However, tactical equipment design often proves to be insufficient when operating in extreme cold temperatures below -25° F. Auxiliary fuel burning and electrical (PTC) heaters are permanently installed in USARAK vehicles as necessary to augment standard vehicle design enough to reach appropriate troop cabin temperatures. This is especially important when transporting Soldiers on troop seats in the cargo areas of FMTV and HMMWV family of vehicles.

d. Water trailers (buffalo) are fitted with a permanently mounted fuel-fired water heater kit. The heater is electrically powered by 24 volt DC battery and draws fuel from an on-board fuel tank to heat and circulate special antifreeze through a closed circuit pipe that is mounted inside the water tank.

Chapter 4
Equipment Operation and Maintenance

4-1. General

TMs provide complete PMCS procedures and must be on hand (hard copy or maintenance support device) for operator and field level maintenance activities. This chapter addresses items and procedures that require special attention during extreme cold weather. While in garrison, when temperatures are below -25° F and during periods of heavy snowfall, USARAK units will increase PMCS frequency to include additional operator PMCS (before, during, after) as required to clear snow from vehicles, circulate fluids, recharge batteries, and exercise tires/seals/belts and other rubber components. Commanders must not allow batteries to completely discharge between weekly PMCS periods on equipment without battery maintainers plugged into Headbolt Outlets (HBO). While in tactical or field training environments during winter months, commanders and maintenance personnel should develop a schedule that requires equipment to be operated on a routine basis to prevent vehicles from becoming cold-soaked. Noise discipline and concealment may have to be sacrificed to maintain equipment operational readiness. A well-planned PMCS program will help minimize time-consuming slave starting and equipment repairs that detract from other training and mission events at critical moments, and the expense associated with replacing components and parts permanently damaged by extreme cold weather. Appropriate time should be factored as a resource requirement during cold temperatures to allow for engine preheats procedures, snow removal, and window defrost before equipment operation is required.

4-2. Lubricants

The LOs and TMs for ground equipment are supplemented by USARAK Regulation 750-4 for all lubricants, fuels, fuel additives, and fluids, and are applicable to all USARAK units and activities while operating ground equipment in Alaska. It is critical for operators and maintainers to utilize the appropriate fluids, as expensive and permanent damage to vehicle components will occur when improper fluids fail to retain proper viscous properties and perform immediately in extreme cold temperatures.

4-3. Chassis and Body Components

a. Ice, mud, and snow can build up on operating vehicles to such an extent that it overloads vehicle components, reduces ground clearance, and prevents or interferes with normal moving component operation. Slush and water buildup and freezing around an operating vehicle's wheels can cause a steering ability loss.

b. Brakes.

(1) Frozen moisture in the air brake system seriously affects operation. Brake lines, air brake filters, brake chambers, push rods, valves, and seals are subject to defects and failure in the cold. Condensation between brake shoes and drums may freeze, making it impossible for the vehicle to move. When this happens, use portable heating equipment to thaw the brake shoes from the drums.

(2) Ensure the alcohol evaporator kit is functioning if it is part of the system. Check the air compressor, the unloader valve, and the governor for good condition and satisfactory operation. With air pressure at the governed maximum and brakes applied, stop the engine. There should not be a noticeable drop in pressure within one minute. Drain reservoirs immediately after operation and close drain cocks immediately after draining to prevent freezing in the open position. Build up brake pressure before the moving the vehicle again.

(3) It is imperative to inspect and maintain hydraulic brake systems during extreme cold temperatures to ensure brake fluid is not contaminated or exposed to moisture/condensation. Contaminated brake fluid is susceptible to freeze within the braking components, rendering the braking system inoperable. Any indication of brake fluid contamination renders the vehicle Non Mission Capable, and requires complete field level maintenance inspection, component repair, and fluid flush.

(4) Do not set the parking brake for extended periods during cold temperatures, since they may freeze and not release. Use chock blocks to hold wheels or tracks in place. If the brake components do freeze in the set position, use an external heat source (portable heater) for thawing, to prevent damage to the vehicle power train. For the Small Unit Support Vehicle (SUSV), apply the parking brakes when stopped since there is not neutral-park gear.

c. Shock absorbers. The light-weight hydraulic oil in shock absorbers is susceptible to extreme cold weather. Check shocks for leaks and breakage at every rest period. After long inactivity periods, move the vehicle out slowly to allow the hydraulic oil to warm up. This helps prevent leakage and provides a smoother ride.

d. Steering system.

(1) Warm up steering systems before movement (especially power steering systems). While the vehicle engine is warming up, move the steering wheel SLOWLY lock to lock. Repeat this a few times to warm the steering system oil. The heat created by the pump's high pressure side will quickly warm the oil to an acceptable operating

temperature. In manual steering systems, this exercise will achieve the same results except it will take more time due to lower friction inherent in unpressurized manual systems.

(2) Examine the arms, tie rods, drag links, seals and boots, pitman arm, gear column, and wheels for good condition and secure mounting. Ensure that the gear case is not leaking and the gears are properly adjusted.

e. SUSV track.

(1) Remove all dirt, snow, and ice and inspect for good condition and proper lubrication. Check the track adjustment. Do not adjust tracks too tightly in a warm shelter since they will contract and break easily in temperatures below -40° F.

(2) SUSV track will warm-up while in use and melt snow on and under itself. After parking in extreme cold temperatures, the water on the SUSV track will freeze and result in the track being frozen to the ground. If track freezes to the ground, use a portable hot air heater to melt away ice from the track. If time is critical, slowly move the vehicle back and forth in an attempt to break away from the frozen ground. If the SUSV has been operated enough to warm the track, park on insulating material to prevent the track from freezing to the ground.

f. Tires.

(1) During extreme cold temperatures, tires become very brittle and sidewalls may contract and separate from wheels. Though they appear to be all right, the tire can slip away from the wheel and tear the tubes and valve stems. With tubeless tires, this slippage can break the seal between the tire and wheel, deflating the tire. Tires may also have a flat spot where they contacted the ground. Move very SLOWLY for the first mile or so, allowing the tires to warm up and become pliable, giving a good seal against the wheel.

(2) Wheel assemblies with two-piece rims must be inspected intensely at temperatures below -25° F during PMCS. The rubber o-ring that seals the mating surface internally between the two rim halves is susceptible to contract and harden, and must be replaced by maintenance personnel if a slow leak is discovered.

(3) During periods of freezing rain, do not park vehicles in areas with pooling water. If operating in areas with pooling water, move vehicles frequently and place insulating material (small branches work in tactical situations) under tires before parking to prevent

tires from freezing to the ground surface. If tires do freeze in place, use a portable hot air heater to melt the tires loose.

g. Springs. Metal, like most other material, becomes brittle in extreme cold weather. Cold-soaked metal can easily snap, causing damage to vehicle and trailer suspension systems. By initially moving SLOWLY, the springs will warm up and regain their elasticity, avoiding damage. Avoid driving into depressions or over obstacles that may cause excessive flexing and possible spring breakage in extreme cold temperatures.

h. Wheel bearings.

(1) No lubricant changes are required since all wheel bearings are serviced for year-round operations with grease (automotive and artillery) that has a temperature range of -65° to +225° F.

(2) Inspect SUSV oil-lubricated road wheel bearings to ensure that water has not collected during operation. If a significant amount of water has collected, seals may rupture as it freezes and expands.

i. Universal and slip joints. Thoroughly lubricate joints with molybdenum disulfide grease.

j. Cab enclosures and Arctic hardtops provide insulation necessary to maintain adequate temperatures for troop comfort and safety. When crossing frozen streams or other bodies of water, open the doors to permit quick personnel escape in the event the vehicle should break through the ice and submerge.

k. Tire chains will be available in every USARAK vehicle on dispatch from 1 Oct through 15 April, and should be inspected to ensure they are serviceable before operation. Require operators/crews to practice mounting and removing them, to ensure they are capable of properly employing them on the correct tires (always across the axle, i.e. do not stagger one left front/one right rear) IAW unit SOP and risk management decisions. Ensure operators and vehicle commanders check the chains frequently at vehicle halts to ensure they retain the appropriate tension, as loose chains will damage the vehicle. Remove chains when not needed to prevent unnecessary damage to the vehicle, wear on the chains, and destruction to ground/road surface. Tire chains are not intended for extended use on asphalt surface, and will wear out prematurely if not employed appropriately.

l. Stryker vehicle hulls must be free of water before parking in freezing temperatures. Fuel, air, hydraulic lines and cylinders are all located in the hull, and susceptible to damage caused by freezing fluid. Install environmental covers over the air intake and exhaust grills to prevent entry of snowfall, which will melt during vehicle operation and freeze in the hull after operation.

4-4. Power Train

a. Engines.

(1) Appropriate engine oil as prescribed in USARAK 750-4 will prevent fluid friction on cylinder walls and bearings. Fluid friction from using higher weight engine oil will place additional strain on the vehicle batteries and starter while starting a cold-soaked engine, in addition to damage sustained initially to internal engine components due to the oil pump inability to circulate thicker fluid. Check the engine oil level before starting and fill to the prescribed level if necessary. As soon as the engine starts check the oil pressure gauge readings, and shut down the engine if oil pressure is not correct within 30 seconds. The low oil pressure warning lights may blink on and off initially when idling at 500 to 650 RPM using appropriate fluids outlined in USARAK 750-4, but should not remain on at higher RPMs.

(2) Extreme cold weather often prevents engines from reaching normal operating temperatures, increases engine carbon development, and increases oil dilution and condensation. These factors all combine to create internal engine sludge. To correct a sludge condition, maintenance personnel must drain the oil while the engine is hot, change the oil filter, and refill with clean oil. If the particular vehicle is enrolled in Army Oil Analysis Program, a special sample will then be submitted. While performing After Operations PMCS, particular attention should be paid to the oil pan, valve cover, timing chain cover, and external oil lines for evidence of oil leaks.

(3) Most fan/serpentine belts used on tactical vehicles are made to retain flexibility in extreme cold temperatures, but particular attention should be paid during Before Operation PMCS to inspection of the belts. Cracks in the rubber will make the belts susceptible to break at a much higher rate in subzero temperatures.

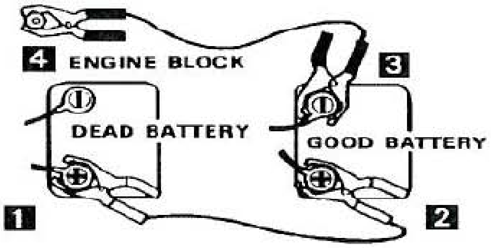
(4) Starting vehicles/equipment in cold and extreme cold temperatures should be performed by carefully following procedures in the appropriate -10 operator TM for Operation Under Unusual Conditions (Cold). Many of the current manuals will direct operators to TM 4-33.31 (formerly FM 9-207) for additional procedures in extreme cold temperatures, as most of the current TMs do not contain procedures for use and operation of USARAK winterization items and procedures. When attempting to start, do not hold the key/switch in the "start" position longer than 15 seconds, and allow 60 seconds for the starter to cool between starting attempts.

(a) Never start a cold-soaked engine without performing preheat procedures. While in a garrison locations (mostly Fort Wainwright) with Headbolt Outlets (HBO) in the tactical motor pools, ensure the vehicle's 120 volt AC block heater remains plugged in. In garrison locations or while in tactical environments, the block heaters are still a simple preheat capability for short duration requirements using tactical power generators. The vehicle fuel-fired engine preheater will be used in all other instances, ensuring a minimum of one hour preheat time is allowed before attempting to start the engine. Stryker vehicle systems have a very specific sequence outlined in the -10 TM to operate the Personnel and Engine Coolant circulating Heater (PECCH), which must be followed to prevent damage to the PECCH components. Pay particular attention to the fuel level in vehicles/equipment with frequent fuel-fired preheater use, as the preheater will consume small amounts of fuel and battery power each time it is operated.

(b) Starting fluid (Ether) will not be used to start cold-soaked engines, as severe internal damage is sustained while metal tolerances and lubrication properties are affected by cold temperatures in an engine that is not properly preheated. Using starting fluid is strictly prohibited at all times if not incorporated in the equipment's original manufacturer's configuration as a system, and employed in accordance with the TM.

(c) Slave/jump starting procedures should never be performed in extreme cold temperatures if the vehicle battery electrolyte condition is unknown. The VLRA-AGM batteries are sealed, making it difficult to determine the state of electrolyte. Dead batteries in USARAK vehicles with frozen electrolyte have exploded while slave starting from another vehicle. If in doubt, move batteries to a location to warm/thaw before attempting to slave start. The vehicle TM provides specific procedures for slave starting. Jump starting equipment without North Atlantic Treaty Organization slave capability using standard "jumper cables" should be connected as illustrated in Table 4-1. Always ensure that the batteries are the same voltage, amperage, and negative posts are properly grounded. Vehicles should not touch each other, and all power, electronics, and communications equipment are off prior to connecting slave or jumper cables.

Table 4-1



(d) Engine idle should be raised to 1000-1200 RPM to circulate coolant and provide proper alternator charge to vehicle batteries. Do not allow engines to idle to operate personnel heaters, and ensure licensed Soldiers are physically present to monitor temperature and pressure gauges while equipment is running. Be sure there is adequate troop compartment ventilation to prevent carbon monoxide poisoning.

b. Transmissions.

(1) Automatic, semi-automatic, and manual transmissions will use oils prescribed in USARAK Pam 750-4 while operating in Alaska. When operating vehicles in extreme cold temperatures, it is imperative to allow appropriate time for a cold-soaked transmission to warm up before moving to prevent damage to internal components from the lack of lubrication.

(2) Operators must be extremely careful when moving a vehicle with congealed gear case lubricants, wheel bearing greases, or tires frozen to the ground. An attempt to operate with these conditions can damage the transmission and other drive train components. Before moving the vehicle, put the transmission in low gear and the transfer unit, where applicable, in low range. Drive the vehicle approximately 100 meters, being careful not to stall the engine, and then up shift. Continue slowly into the higher gears until the vehicle moves freely and/or tire thump ceases.

(3) When preparing a vehicle for shut down, place the transmission and transfer unit shift levers in the neutral position. This prepares the units for the next start by preventing them from freezing in an engaged position.

c. Cooling systems in all USARAK vehicles/equipment should meet extreme cold temperature requirements year-round.

(1) An approximate mix of three parts antifreeze (ethylene glycol, inhibited (MIL-A-46153)) to two parts water (3:2 ratio) will provide protection down to approximately -60° F. Test all antifreeze protection levels during scheduled field maintenance services (minimum annually if enrolled in Low Usage) with a hydrometer or view type tester. Record the cooling system protection level on the SAMS-1E equipment records (minimum annually if enrolled in Low Usage) with a hydrometer or view type tester. Record the cooling system protection level on the SAMS-1E equipment records (DA 5988-E) filed in the vehicle service packet. Refer to Table 4-2 for antifreeze requirements to provide protection levels.

(2) If engine coolant is determined to be frozen during Before Operations PMCS, employ engine preheat devices (block heater or fuel-fired preheater) to warm the

engine. Inspect for any possible leaks or cooling system damage caused by expansion of the coolant. Operating an engine with frozen coolant without proper preheat procedures during extreme cold temperatures could result in burst hoses or water pump damage.

Table 4-2
Antifreeze Protection Table

Cooling System Quart Capacity	Quarts of Antifreeze Coolant Required For Protection to Temperature Points Fahrenheit Shown Below											
	2	3	4	5	6	7	8	9	10	11	12	13
5	-12°	-62°										
6	0°	-34°										
7	6°	-17°	-54°									
8	10°	-7°	-34°	-69°								
9		0°	-21°	-50°								
10		4°	-12°	-34°	-62°							
11		8°	-6°	-23°	-47°							
12		10°	0°	-15°	-34°	-57°						
13				-9°	-25°	-45°	-66°					
14				-5°	-17°	-34°	-54°					
15				0°	-12°	-26°	-43°	-62°				
16				2°	-7°	-19°	-34°	-52°				
17				5°	-4°	-14°	-27°	-42°	-58°			
18				7°	0°	-10°	-21°	-34°	-50°	-65°		
19				9°	2°	-7°	-16°	-28°	-42°	-56°		
20				10°	4°	-3°	-12°	-22°	-34°	-48°	-62°	
21					6°	0°	-9°	-17°	-28°	-41°	-54°	-68°
22					8°	2°	-6°	-14°	-23°	-34°	-47°	-59°
23					9°	4°	-3°	-10°	-19°	-29°	-40°	-52°
24					10°	5°	0°	-7°	-15°	-24°	-34°	-46°

Guide for Preparation of Ethylene-Glycol Antifreeze Solutions

Do Not use without some water; 68% concentration gives maximum protection

Use at least 25% concentration for protection against rust and corrosion

d. Fuel System.

(1) During cold temperatures, condensation can easily build up in tanks, drums, containers, fuel pumps, fuel lines, injectors, and carburetors. At low temperatures, this condensation will form ice crystals that will clog injector nozzles, carburetor jets, fuel lines, filters, and pumps. Anti-icing additive usage will eliminate the condensation. Keep fuel tanks filled to the appropriate expansion level which will reduce space in the tank for condensation to form, and ensure to wipe snow from dispensing equipment and around the fuel tank before refueling. Fuel tanks should not be completely filled in cold temperatures if determined the vehicle will be moved to a warm location/indoors, as expansion of the fuel in the tank may cause spillage.

(2) Drain fuel filters in accordance with the equipment TMs at the end of each day of operations. Do not assume that the filter is dry if nothing flows from the drain cock. If water is present, it may be frozen in the filter housing.

e. Hydraulic System.

(1) Hydraulic systems will use fluids prescribed in USARAK Regulation 750-4 while operating in Alaska or any Arctic location where extreme cold temperatures are suspected.

(2) Hydraulic systems should not be allowed to cold soak if immediate use is required. Most material handling equipment, cranes, wreckers, and construction equipment have large-volume hydraulic tanks, pumps, lines, valves, and cylinders which hold a substantial volume of hydraulic fluid, which must be gradually warmed prior to using the equipment. If cold-soaked in extreme cold temperatures, the hydraulic system must be operated (under no load) for one hour to prevent equipment damage and prevent environmental spills which result from ruptured hydraulic lines, blown seals, or cracked component housings.

4-5. Electrical System

a. One of the greatest hindrances to successful military operations in Arctic conditions is the extreme cold temperature effects on batteries. Temperature effects, combined with the lack of preventive maintenance result in a significant reduction in battery life expectancy. Most vehicles in USARAK utilize VRLA-AGM batteries, which provide benefits associated with a maintenance-free battery and the increased ability to recover/recharge multiple times after a complete loss of charge. Never mix VRLA-AGM batteries with conventional flooded-cell lead acid batteries in multi-battery electrical systems.

(1) At temperatures below 32° F, the battery electrochemical reaction time prolongs the time required to recharge. Vehicle batteries should be maintained at a full state of charge to ensure proper electrolyte condition, and reduction in time required to recover the loss of battery charge from cranking and use of electronic and communications equipment. Battery maintainers should remain plugged in during periods of extreme cold temperatures to ensure batteries do not deplete and freeze between PMCS periods. Extended engine run time above idle RPM is necessary to provide proper recharge of batteries during sub-zero temperatures, and the VRLA-AGM batteries have proven to take longer than standard flooded-cell batteries to return to a full state of charge.

(a) VLRA-AGM vehicle batteries are sealed and do not require the addition of water or electrolyte. VRLA-AGM batteries will freeze in extreme cold temperatures if not maintained at a full state of charge, but are usually recoverable and recharge once thawed.

(b) Flooded-cell vehicle batteries require electrolyte maintenance. Consider 1.280 specific gravity the optimum level for a charged battery. Do not add distilled water to a battery during extreme cold temperatures, as the water will not mix with the electrolyte and will freeze in the battery. A frozen flooded-cell battery should be considered damaged and disposed of without attempting to thaw or recharge.

(2) A battery will more readily accept a charge at warmer temperatures (above 35° F). If it is necessary to recharge a battery at low temperatures, the charging voltage should be low enough to prevent excessive electrolyte boiling. Never attempt to recover/recharge a frozen battery. Specific guidance on field level maintenance, testing, and recharging of vehicle batteries is provided in the USARAK Battery Maintenance Program memorandum and TM 9-6140-200-13 (Maintenance for Automotive Lead Acid Storage Batteries).

b. Vehicle-mounted electronic components and C4ISR equipment are extremely sensitive, and will malfunction if circuits are exposed to moisture or improperly operated in extreme cold temperatures.

(1) Snow, ice, and condensation should be removed from electrical/electronic components. Ensure vehicle cupolas, gunner hatches, etc.; remain closed when not occupied, to shield sensitive components from snowfall. If internal moisture is suspected to have occurred on sensitive electronic components, no not operate or apply electrical power as costly damage may occur. Remove the components from the vehicle, or move the entire vehicle to an area to thoroughly warm and dry the affected items prior to applying electrical power.

(2) C4ISR components should not be allowed to cold soak if immediate use is anticipated. Most display panels (LCD) have internal heating elements which enable normal operation, but for normal planning purposes electronic equipment exposed to extreme cold temperatures should be preheated or warmed with vehicle heat for one hour prior to use to prevent electrical power being applied to frozen circuitry.

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Commanding

Appendix A.
Lubricants.

A-1. Gasoline, diesel, and multifuel engines. USARAK commanders will utilize only Oil, Engine, Synthetic, OEA, 0W30 on a year round basis unless otherwise specified by the component manufacturer. Table A-1 shows the lubricant's temperature limitations for gasoline, diesel, and multifuel engine usage.

Table A-1.
Gasoline, diesel, and multifuel engine lubricant temperature limitations

Lubricant	Lower Limitation	Upper Limitation
OEA 0W30	-67 degrees Fahrenheit*	+90 degrees Fahrenheit

*This temperature is without external heaters. With heat, oil is satisfactory at much lower temperatures.

A-2. Transmissions, gear cases, and hydraulic and power steering systems. Table A-2 shows the temperature limitations for the lubricants used in this equipment.

a. Automatic transmissions and hydraulic and power steering systems. Use OEA 0W30 in automatic transmissions and hydraulic and power steering systems on a year-round basis. OEA 0W30 is compatible with all types of automatic transmission fluids (including Dexron III). OEA 0W30 can be mixed with other transmission fluids or other transmission fluids can be added to it.

b. Semiautomatic transmissions (including all Caterpillar series transmissions). When temperatures permit, 15W40 is the preferred oil for these transmissions.

c. Allison transmissions utilized in the FMTV will use OEA 0W30 only.

Table A-2.
Transmission, gear case, and hydraulic and power steering system lubricant temperature limitations

Lubricant	Lower Limitation	Upper Limitation
15W40	-10 degrees Fahrenheit	+212 degrees Fahrenheit
OEA 0W30	-67 degrees Fahrenheit	+90 degrees Fahrenheit

A-3. Gear cases. Manual transmissions, transfers, differentials, and final drives that normally utilize GO90/140; use oil, gear, 75/90 Synthetic. Some manufacturers may require different lubricants in specific applications; for example, the HEMTT and the HMMWV transfer cases use OEA 0W30.

A-4. Chassis. Use grease, automotive and artillery (GAA) for chassis lubrication, including wheel bearings.

A-5. Weapons. Table A-3 shows the temperature limitations for the lubricants used in weapons.

a. Small arms and machine guns.

(1). Use lubricating oil, weapon (LAW), lubricating oil, small arms (LSA), cleaner lubricant and preservative (CLP), and rifle bore cleaner (RBC) on your weapons.

(2). Do not mix lubricants on the same weapon. Thoroughly clean the weapon when changing from one lubricant to another. PRF-680 is recommended for cleaning when changing from one lubricant to another.

Appendix B.
Fuels and Fuel Additives.

B-1. Gasoline, Automotive, Unleaded or Low-lead, VV-G-1690B. Unleaded gasoline is the only fuel authorized for gasoline-powered equipment.

B-2. Diesel Fuel. Use JP-8 for all multifuel- and diesel-powered equipment.

B-3. Additives. Ether. Using ether or a similar-type fluid as a starting aid is strictly prohibited, except when the equipment's original configuration includes such a system as a starting aid. The factory-installed systems meter a mixture into the engine that will not cause damage. Using a spray can or other means to inject a mixture into the engine is likely to cause internal engine damage and is extremely dangerous to personnel.

Appendix C.
Miscellaneous Fluids.

C-1. Brake fluid. The only brake fluid authorized for use is as specified in the vehicle lubrication order (LO).

C-2. Alcohol evaporator systems. Vehicles equipped with air braking systems must have an operable alcohol evaporator system which draws vaporized alcohol into the compressed air system or an air dryer system installed during cold weather (0 degrees to -65 degrees Fahrenheit). These systems are designed to prevent the forming and freezing of condensation in the air systems. An inoperable alcohol evaporative system or air dryer system from 1 October through 31 April renders the vehicle not mission capable (NMC)

a. A bolt-on type evaporator kit is available under national stock number 2530-00-859-7335.

b. Use only methanol technical, type OM 232 in this system.

Table II. Application of Antifreeze Materials, Fuels, Hydraulic Fluids, and Lubricants in Extreme Cold—Continued

Application	Antifreeze materials, fuels, hydraulic fluids, and lubricants[1]
FUEL SYSTEMS:	
Combat and tactical vehicles, gasoline engine-driven generators, marine and rail equipment.	GASOLINE, AUTOMOTIVE: 88 octane premium grade, class C. 1. Overseas—when available. 2. Will be used in Continental United States. 3. Drain fuel tank sump and add ½ pint of DENATURED ALCOHOL (grade III) to each 10 gallons of fuel at time of filling and thereafter. GASOLINE, AUTOMOTIVE: 91 octane, type I (91A) and type II (91C). 1. Overseas. *a.* All combat and tactical transport vehicles. *b.* All materiel and equipment used in maneuvers. *c.* All NATO pipeline movements. 2. Continental United States—all materiel and equipment used in maneuvers. 3. Drain fuel tank sump and add ½ pint of DENATURED ALCOHOL (grade III) to each 10 gallons of fuel at time of filling and thereafter.
Nontactical vehicles, material and equipment, including stationary internal-combustion spark-ignition engines.	GASOLINE, AUTOMOTIVE: 82 octane, amend. 2, regular grade, class C. 1. Overseas—when available. 2. Will be used in Continental United States. 3. Drain fuel tank sump and add ½ pint of DENATURED ALCOHOL (grade III) to each 10 gallons of fuel at time of filling and thereafter. GASOLINE, AUTOMOTIVE: 91 octane, type I (91A) and type II (91C). When prescribed in manufacturer's (or military) specifications or operating manuals.
GEAR CASES (differential, final drives, right-angle drive, steering, transmission, and transfer).	LUBRICATING OIL (GOS). LUBRICATING OIL (OES) wherever LUBRICATING OIL (SAE 10) is specified.
GEARS	LUBRICATING OIL (GOS).
GENERATOR:	
Ball bearings (unsealed)	GREASE (GL).
Generator	LUBRICATING OIL (PL, special).
GOVERNOR:	
Rocker arm	GREASE (GAA).
Valve	LUBRICATING OIL (OES).
GUN:	
Cradle and bushing	GREASE (GAA).
Elevating and pinion gear	
Firing mechanism control cable	
Mount (small arms)	
Tube (threaded portions at muzzle brake)	
Tube key	
HOIST-WINCH HYDRAULIC RESERVOIR	LUBRICATING OIL (OES).
HOWITZER:	
Bore	LUBRICATING OIL (PL, special).
Firing mechanism	
Mount connecting linkage	
Safety latch	
Tube	GREASE (GAA).
HYDRAULIC GEARS	HYDRAULIC FLUID (OHC).
HYDRAULIC POWER PACK	HYDRAULIC FLUID (OHC).
HYDROVAC UNITS	HYDRAULIC FLUID (OHC).

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[1] See footnote at end of table.

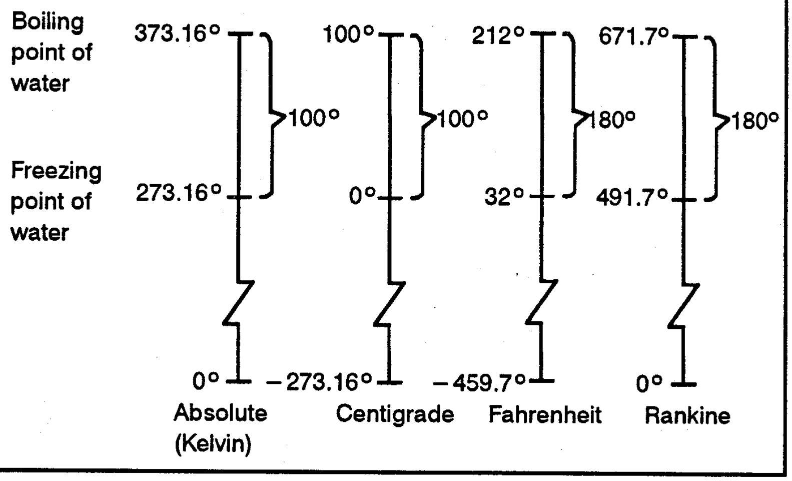
METRIC/ENGLISH CONVERSION CHARTS

CENTIGRADE–FAHRENHEIT CONVERSION

C	F	C	F	C	F	C	F
−75	−103	40	104	155	311	537.8	1000
73.3	−100	43.3	110	160	320	550	1022
−70	−94	45	113	165	329	593.3	1100
−67.8	−90	48.9	120	165.6	330	600	1112
−65	−85	50	122	170	338	648.9	1200
−62.2	−80	54.4	130	171.1	340	650	1202
−60	−76	55	131	175	347	700	1292
−56.7	−70	60	140	176.7	350	704.4	1300
−55	−67	65	149	180	356	750	1382
−51.1	−60	65.6	150	182.2	380	760	1400
−50	−58	70	158	185	365	800	1472
−45.6	−50	71.1	160	187.8	370	815.6	1500
−45	−49	75	167	190	374	850	1562
−40	−40	76.7	170	193.3	380	871.1	1600
−35	−31	80	176	195	383	900	1652
−34.4	−30	82.2	180	198.9	390	926.7	1700
−30	−22	85	185	200	392	950	1742
−28.9	−20	87.8	190	204.4	400	982.2	1800
−25	−13	90	194	225	437	1000	1832
23.3	−10	93.3	200	232.2	450	1037.8	1900
−20	−4	95	203	250	482	1050	1922
−17.8	0	98.9	210	260	500	1093.3	2000
−15	5	100	212	275	527	1100	2012
−12.2	10	104.4	220	287.8	550	1148.9	2100
−10	14	105	221	300	572	1150	2102
−6.7	20	110	230	315.6	600	1200	2192
−5	23	115	239	325	617	1204.4	2200
−1.1	30	115.6	240	343.3	650	1250	2282
0	32	120	248	350	662	1260	2300
4.4	40	121.1	250	371.1	700	1300	2372
5	41	125	257	375	707	1315.6	2400
10	50	126.7	260	398.9	750	1350	2462
15	59	130	266	400	752	1371.1	2500
15.6	60	132.2	270	425	797	1400	2552
20	68	135	275	426.7	800	1426.7	2600
21.1	70	137.8	280	450	842	1500	2732
25	77	140	284	454.5	850	1537.8	2800
26.7	80	143.3	290	475	887	1550	2822
30	86	145	293	482.2	900	1593.3	2900
32.2	90	148.9	300	500	932	1600	2912
35	95	150	302	510	950	1648.9	3000
37.8	100	154.4	310	525	977	1650	3002

Temperature may be expressed in terms of any of these scales: Centigrade (°C), Absolute or Kelvin (°A or °K), Fahrenheit (°F), or Rankine (°R)

$^\circ K = {}^\circ A - ({}^\circ C + 273.16)$
$^\circ K = {}^\circ A = {}^\circ R\ 5/9$
$^\circ K = {}^\circ A = ({}^\circ F - 32)\ 5/9 + 273.16$
$^\circ C = A - 273.16$
$^\circ C = ({}^\circ F - 32)\ 5/9$
$^\circ C = {}^\circ R\ 5/9 - 273.16$
$^\circ F = {}^\circ C\ 9/5 + 32$
$^\circ F = ({}^\circ A - 273.16)\ 9/5 + 32$
$^\circ F = {}^\circ R - 459.7$
$^\circ R = {}^\circ F + 459.7$
$^\circ R = {}^\circ A\ 9/5$
$^\circ R = ({}^\circ C + 273.16)\ 9/5$



Motion – Rectilinear

Linear Velocity (LT^{-1})

Multiply	By	To Obtain	Multiply	By	To Obtain
centimetres/second	1.968	feet/minute	kilometres/min	1.666.7	centimetres/sec
feet/hour	30.48	centimetres/hr	kilometres/min	54.68	feet/sec
feet/hr	0.01667	feet/min	kilometres/min	32.397	knots
feet/hr	$1.646/10^4$	knots	kilometres/min	37.28	miles/hour
feet/hr	$1.894/10^4$	miles/hour	knots	51.44	centimetres/sec
feet/min	0.5080	centimetres/sec	knots	101.27	feet/min
feet/min	0.01667	feet/sec	knots	1.6878	feet/sec
feet/min	0.009875	knots	knots	1.852	kilometres/hour
feet/min	0.3048	metres/min	knots	1	nautical miles/hr
feet/min	0.01136	miles/hr	knots	1.1508	miles/hr
feet/sec	30.48	centimetres/sec	metres/min	1.667	centimetres/sec
feet/sec	1.097	kilometres/hr	metres/min	196.85	feet/hr
feet/sec	0.5925	knots	metres/min	0.0547	feet/sec
feet/sec	0.6818	miles/hr	metres/min	0.032397	knots
inches/hr	0.04233	centimetres/min	metres/min	0.03728	miles/hr
inches/min	152.4	centimetres/hr	meters/sec	196.85	feet/min
inches/min	0.0423	centimetres/sec	metres/sec	3.281	feet/sec
inches/min	0.001389	feet/sec	metres/sec	1.944	knots
inches/sec	152.4	centimetres/min	metres/sec	2.2369	miles/hr
inches/sec	0.08333	feet/sec	miles/hr	44.70	centimetres/sec
inches/sec	0.05682	miles/hr	miles/hr	88	feet/min
kilometres/hr	27.78	centimetres/sec	miles/hr	1.4667	feet/sec
kilometres/hr	54.68	feet/min	miles/hr	17.6	inches/sec
kilometres/hr	0.9113	feet/sec	miles/hr	1.6093	kilometres/hr
kilometres/hr	0.53996	knots	miles/hr	0.86898	knots
kilometres/hr	0.6214	miles/hr	miles/hr	0.4470	metres/sec

Linear Acceleration (LT^{-2})

Multiply	By	To Obtain	Multiply	By	To Obtain
centimetres/sec/sec	0.036	kilometres/hr/sec	kilometres/hr/sec	0.9113	feet/sec/sec
centimetres/sec/sec	1.342	mph/min	metres/sec/sec	3.6	kilometres/hr/sec
centimetres/sec/	0.0224	mph/sec	metres/sec/sec	2.237	mph/sec
feet/sec/sec	1.097	kilometres/hr/sec	mph/sec	44.70	centimetres/sec/sec
feet/sec/sec	0.3048	metres/sec/sec	mph/sec	1.467	feet/sec/sec
feet/sec/sec	0.6818	mph/sec	mph/sec	1.609	kilometres/hr/sec
kilometres/hr/sec	27.78	centimetres/sec/sec	mph/sec	0.4470	metres/sec/sec

Equations

Velocity: the rate of change of displacement with respect to time:

$$v = ds/dt, \ v \, dv - a \, ds$$

when a is constant

$$V_t = V_o, at$$

Displacement: the amount of change in position

$$ds = v \, dt$$

when a = constant

$$S = V_t{}^2 - V_o{}^2/2a$$

$$S = V_o \, t, at^2/2$$

Acceleration:

$$a = dv/dt$$

when a = constant

$$a = \frac{V_t - V_o}{t}$$

Length (L)

Multiply	By	To Obtain
angstrom	0.1	nanometre
angstrom units	$1/10^{10}$	metres
centimetres	0.3937	inches
centimetres	0.01	metres
centimetres	393.7	mils
decimetres	0.1	metres
dekometres	10	metres
fathoms	6	feet
feet	0. 3048	metres
furlongs	660	feet
furlongs	40	rod
hands	4	inches
hectometres	100	metres
inches	25.40	millimetres
inches	1000	mils
kilometres	3281	feet
kilometres	1000	metres
kilometres	0.6214	miles
kilometres	0.53996	nautical miles
kilometres	1094	yards
leagues	3	miles
light years	5.88×10^{12}	miles
links (engineer's)	12	inches
links (surveyor's)	7.92	inches
metres	3.2808	feet
metres	39.37	inches
metres	$6.214/10^4$	miles
metres	1.0936	yards
micron	1	micrometre
microns	$1/10^6$	metres
microns	0.03937	mils
miles	5280	feet
miles	1609	metres
miles	1760	yards
millimetres	0.03937	inches
millimetres	0.001	metres
millimetres	39.37	mils
mils	0.001	inches
mils	0.02540	millimetres
myriametres	10,000	metres
nautical miles	6076.1	feet
nautical miles	1852	metres
nautical miles	1.1508	miles
nautical miles	2025.4	yards
rods	16.5	feet
statute miles	1760	yards
statute miles	5280	feet
statute miles	1.6094	kilometres
statute miles	0.8690	nautical miles
yards	0.9144	metres
yards	$5.682/10^4$	miles
yards	$4.937/10^4$	nautical miles

Area (L^2)

Multiply	By	To Obtain
acres	43,550	square feet
acres	0.004047	square kilometres
acres	4047	square metres
acres	0.001563	square miles
acres	4,840	square yards
centares	1	square metres
circular mils	$5.067/10^6$	square centimetres
circular mils	$0.7854/10^6$	square inches
circular mils	$5.067/10^4$	square millimetres
circular mils	0.7854	square mils
hectares	10,000	square metres
square centimetres	1.973×10^5	circular mils
square centimetres	0.001076	square feet
square centimetres	0.1550	square inches
square centimetres	$1/10^4$	square metres
square centimetres	100	square millimetres
square feet	929.0	square centimetres
square feet	144	square inches
square feet	0.09290	square metres
square feet	1/9	square yards
square inches	6.452	square centimetres
square inches	0.006944	square feet
square inches	$6.452/10^4$	square metres
square inches	654.2	square millimetres
square inches	10^6	square mils
square kilometres	247.1	acres
square kilometres	10.76×10^6	square feet
square kilometres	10^6	square metres
square kilometres	0.3861	square miles
square kilometres	1.196×10^6	square yards
square metres	$2.471/10^4$	acres
square metres	10.76	square feet
square metres	1.196	square yards
square miles	640	acres
square miles	27.88×10^6	square feet
square miles	2.590	square kilometres
square miles	3.098×10^6	square yards
square millimetres	1,974	circular mils
square millimetres	0.00155	square inches
square millimetres	$1/10^6$	square metres
square mils	1550	square mils
square mils	1.273	circular mils
square mils	$6.542/10^6$	square centimetres
square mils	$1/10^6$	square inches
square mils	$6.452/10^4$	square millimetres
square yards	9	square feet
square yards	1,296	square inches
square yards	0.8361	square metres

Volume (L^3)

Multiply	By	To Obtain
acre–feet	43,560	cubic feet
acre–feet	1,233	cubic metres
acre–feet	3.259×10^5	gallons
barrel (US)	0.1589	cubic metres
board–feet	144	cubic inches
bushels	1.244	cubic feet
bushels	0.03524	cubic metres
bushels	35.24	litres
bushels	4	pecks
bushels	32	quarts (dry)
centilitres	0.01	litres
cord–feet	4 ft x 4 ft x 1 ft	cubic feet
cords	8 ft x 4 ft x 4 ft	cubic feet
cubic centimetres	0.06102	cubic inches
cubic centimetres	0.001	litres
cubic centimetres	0.03381	fluid ounces
cubic centimetres	0.002113	pints (liquid)
cubic feet	0.80357	bushels
cubic feet	1,728	cubic inches
cubic feet	0.02832	cubic metres
cubic feet	1/27	Cubic yards
cubic feet	7.481	gallons
cubic feet	28.32	litres
cubic feet	62.4	lbs of water 39.2F
cubic feet	29.92	quarts (liquid)
cubic inches	16.39	cubic centimetres
cubic inches	$5.787/10^4$	cubic feet
cubic metres	28.38	bushels
cubic metres	35.31	cubic feet
cubic metres	61,203	cubic inches
cubic metres	1.308	cubic yards
cubic metres	264.2	gallons
cubic metres	1,000	litres
cubic metres	2,203	lbs of water 39.2F
cubic yards	21.70	bushels
cubic yards	27	cubic feet
cubic yards	46.656	cubic inches
cubic yards	0.7646	cubic metres
cubic yards	202.0	gallons
cubic yards	764.5	litres
cubic yards	1,685	lbs of water 39.2F
cupfuls	1/2	pints (liquid)
decilitres	1/10	litres
dekalitres	10	litres
fluid ounce (UK)	28.413	cubic centimetres
fluid ounce (US)	29.574	cubic centimetres
gallons	0.1337	cubic feet
gallons	231	cubic inches
gallons	3.785	cubic centimetres
gallons (US)	0.003785	cubic metres

Multiply	By	To Obtain
gallon (UK)	4546.1	cubic centimetres
gallons	3.785	litres
gallons	8	pints (liquid)
gallons	8.34	lbs of water 39.2F
gallons (Imperial)	1.201	gallons
gills	7.219	cubic inches
gills	1/4	pints (liquid)
hectolitres	100	litres
kilolitres	1,000	litres
litres	0.02838	bushels
litres	1,000	cubic centimetres
litres	0.03532	cubic feet
litres	61.03	cubic inches
litres	0.001308	cubic yards
litres	0.2642	gallons
litres	2.113	pints (liquid)
litres	2.20	lbs of water 39.2F
litres	0.9081	quarts (dry)
litres	1.057	quarts (liquid)
microlitres	$1/10^6$	litres
mil–feet (circular)	$1.545/10^4$	cubic centimetres
mil–feet (circular)	$9.425/10^6$	cubic inches
mililitres	0.001	litres
pecks	1/4	bushels
pecks	8.81	litres
pecks	8	quarts (dry)
perches	24.75	cubic feet
perches	0.7008	cubic metres
pints (dry)	33.60	cubic inches
pints (dry)	1/2	quarts (dry)
pints (liquid)	28.88	cubic inches
pints (liquid)	0.8594	pints (dry)
pints (liquid)	1.042	lbs of water 39.2F
pints (liquid)	1/2	quarts (liquid)
lbs of water 39.2F	0.01602	cubic feet
lbs of water 39.2F	27.68	cubic inches
lbs of water 39.2F	0.1198	gallons
lbs of water 39.2F	0.4536	litres
quarts (dry)	1/32	bushels
quarts (dry)	67.20	cubic inches
quarts (dry)	1.101	litres
quarts (dry)	1.164	quarts (liquid)
quarts (liquid)	946.4	cubic centimetres
quarts (liquid)	57.75	cubic inches
quarts (liquid)	0.9463	litres
quarts (liquid)	2	pints (liquid)
quarts (liquid)	0.8594	quarts (dry)
steres	1,000	litres
tablespoons	1/16	cupfuls
teaspoons	1/3	tablespoons

Volume (L_3)
General Properties of Air

9 = Graviational acceleration – ft/sec$_2{}^2$
P = Absolute pressure – lb/ft^2
q = Dynamic pressure – lb/ft^2
v = Specific volume – ft^3/lb
T = Absolute temperature – °R
R = Universal gas constant – ft lb/lb/°R
V = Velocity – ft/sec
n = Polytropic exponent – Dimensionless
p = Mass density – lb sec^2/ft^4
μ = Absolute viscosity – lb sec/ft^2
v = Kinematic viscosity μ/ϱ – ft^2/sec
σ = Relative density – Dimensionless

Composition of Air

(Standard atmosphere) (ARDC model atmosphere)

The air of the standard atmosphere is assumed to be dry and to have the following composition at altitudes to 300,000 ft

Constituent Gas	Mol. Fraction Percent	Molecular Weight (= 16.0000
Nitrogen (N_2)	78.09	28.016
Oxygen (O_2)	20.95	32.0000
Argon (A)	0.93	39.944
Carbon dioxide (CO_2)	0.03	44.010
Neon (Ne)	1.8×10^{-3}	20.183
Helium (He)	5.24×10^{-4}	4.003
Krypton (kr)	1.0×10^{-4}	83.7
Hydrogen (H^2)	5.0×10^{-5}	2.0160
Xenon (Xe)	8.0×10^{-6}	131.3
Ozone (O_3)	1.0×10^{-6}	48.0
Radon (Rn)	6.0×10^{-18}	222.0

Sea Level Properties

t_o	Standard temperature	59.0°F
T_o	Standard temperature (absolute)	518.67°R
P_o	Standard pressure	29.921260 in Hg 2116.22 lb/sq ft
ϱ_o	Standard density	0.076474 lb/cu ft
M_o	Molecular weight	28.9644 (dimensionless)
ω_o	Standard specific weight	0.07647455 lb/cu ft
R^o	Gas constant (dry air)	8314.32 joules/kg/°K 53.35 ft lb/lb/°K
C^{so}	Speed of sound	1116.4 ft/sec
μ	Coefficient of absolute viscosity	3.7371674×10^{-7} lb sec/sq ft
η^o	Coefficient of kinematic viscosity	1.57232×10^{-4} sq ft/sec
9^o	Standard gravitation acceleration	32.1741 ft/sec/sec

Fathoms/Metres Conversion Table

C 0–499 FATHOMS TO METRES

*(The conversions below 12 fathoms are only to be used in converting depths over 500 fathoms **Table D**)

fm	0	1	2	3	4	5	6	7	8	9
0	*0	*2	*4	*5	*7	*9	*11	*13	*15	*16
10	*18	*20	22	23	25	27	29	31	33	34
20	36	38	40	42	44	46	48	49	51	53
30	55	57	59	60	62	64	66	68	69	71
40	73	75	77	79	80	82	84	86	88	90
50	91	93	95	97	99	101	102	104	106	108
60	110	112	113	115	117	119	121	123	124	126
70	128	130	132	134	135	137	139	141	143	144
80	146	148	150	152	154	155	157	159	161	163
90	165	166	168	170	172	174	176	177	179	181
100	183	185	187	188	190	192	194	196	198	199
110	201	203	205	207	208	210	212	214	216	218
120	219	221	223	225	227	229	230	232	234	236
130	238	240	241	243	245	247	249	251	252	254
140	256	258	260	262	263	265	267	269	271	272
150	274	276	278	280	282	283	285	287	289	291
160	293	294	296	298	300	302	304	305	307	309
170	311	313	315	316	318	320	322	324	326	327
180	329	331	333	335	336	338	340	342	344	346
190	347	349	351	353	355	357	358	360	362	364
200	366	368	369	371	373	375	377	379	380	382
210	384	386	388	390	391	393	395	397	399	401
220	402	404	406	408	410	411	413	415	417	419
230	421	422	424	426	428	430	432	433	435	437
240	439	441	443	444	446	448	450	452	454	455
250	457	459	461	463	465	466	468	470	472	474
460	475	477	479	481	483	485	486	488	490	492
270	494	496	497	499	501	503	505	507	508	510
280	512	514	516	518	519	521	523	525	527	529
290	530	532	534	536	538	539	541	543	545	547
300	549	550	552	554	556	558	560	561	563	565
310	567	569	571	572	574	576	578	580	582	583
320	585	587	589	591	593	594	596	598	600	602
330	604	605	607	609	611	613	614	616	618	620
340	622	624	625	627	629	631	633	635	636	638
350	640	642	644	646	647	649	651	653	655	657
360	658	660	662	664	666	668	669	671	673	675
370	677	678	680	682	684	686	688	689	691	693
380	695	697	699	700	702	704	706	708	710	711
390	713	715	717	719	721	722	724	726	728	730
400	732	733	735	737	739	741	742	744	746	748
410	750	752	753	755	757	759	761	763	764	766
420	768	770	772	774	775	777	779	781	783	785
430	786	788	790	792	794	796	797	799	801	803
440	805	807	808	810	812	814	816	817	819	821
450	823	825	827	828	830	832	834	836	838	839
460	841	843	845	847	849	850	852	854	856	858
470	860	861	863	865	867	869	871	872	874	876
480	878	880	881	883	885	887	889	891	892	894
490	896	898	900	902	903	905	907	909	911	913

For soundings over 500 fm select to the nearest 100 fm below and convert to metres from Table D. To this add converted depths from Table C.

D 500–6000 FATHOMS TO METRES

fm	m	fm	m	fm	m	fm	m
500	914	**1000**	1829	**1500**	2743	**2000**	3658
600	1097	**1100**	2012	**1600**	2926	**3000**	5486
700	1280	**1200**	2195	**1700**	3109	**4000**	7315
800	1463	**1300**	2377	**1800**	3292	**5000**	9144
900	1646	**1400**	2560	**1900**	3475	**6000**	10,973

Reproduction from modified British Admiralty Conversion Tables

ANNEX D

BATTERY MAINTENANCE, EQUIPMENT SAFETY AND CHEMICALS BATTERY MAINTENANCE

1. **Daily**. See that all parts of the ventilation system in battery rooms and battery lockers are in proper condition. Clean battery hydrometers.

2. **Weekly.** Observe the height of electrolyte in cells and measure readings and record cell specific gravity and temperature readings for all batteries (when batteries are in relatively warm rooms). Fill water batteries (only with distilled water) if the height of electrolyte is at the low mark or will drop below the low mark before the next weekly inspection. Check the charging rate of engine battery charging generators and voltage at which batteries are being floated.

3. **Monthly.** Clean batteries and grease the terminals with petrolatum as necessary. Examine battery connections and correct any faulty condition such as breaks, frayed insulation or grounds. Inspect for broken or cracked battery cases or jars. Give all batteries an equalizing charge, except those charged from their own generator or being floated. Take a complete set of voltage, temperature and specific gravity readings on all batteries, which have been given an equalizing charge.

4. **Quarterly**. Give all batteries which are charged from their own generators or are being floated an equalizing charge and take a complete set of voltage, temperature and specific gravity readings.

5. **Semi-Annually**. Give each battery a test discharge at a 5-to-10 hour rate or as specified on the battery nameplate. A test discharge is the most reliable means of determining storage battery conditions, but functional testing may be done in lieu of a test discharge if authorized by the ship's maintenance requirement cards.

6. Functional testing of Navy-type portable storage batteries for various shipboard applications varies with usage, size of battery and load. Test requirements are:

   a. Engine starting batteries should be capable of starting an engine at least once a week.

   b. Portable lantern batteries (using storage lead-acid batteries) should be capable of providing sufficient light for a period of one minute without dimming and should be tested at least once a week.

   c. Gyrocompass batteries should be functionally tested for a 20-minute period on battery power alone, once a month.

   d. Telephone batteries should be functionally tested during a peak load period for 4 hours on battery power alone, once a month.

7. Functional testing of other portable storage battery service not covered above may be obtained upon request from NAVSEA. You will need this information for new applications.

8. In case of failure, give the battery an equalizing charge, then retest. If the retest fails, replace the failed battery.

9. Batteries subjected to the cold should be heated, if possible, and must be kept fully charged to prevent freezing. If you use heaters or a warm air supply to heat boat engines, heat the batteries by the same method. Battery chargers should be provided for all boat batteries, if possible. The battery

charger should be placed in the same temperature environment as the battery being charged since they have a temperature compensation feature for charging voltage.

10. Battery chargers located in heated spaces, used to charge batteries by long leads outside the spaces, should have their charging voltage output adjusted for the exterior temperature, by using the formula:

$V = [2.35 + 0.003(80-T)] \times N$

Where V is the charging voltage, T is the exterior temperature in °F and N is the number of cells in the battery.

11. Any acid batteries, which are required to operate consistently in temperatures below 44°C may have the average specific gravity raised to 1.280 (between limits of 1.270 to 1.285) by adding diluted acid. NAVSEA requires that, this be done by authorized personnel only, as described in NSTM, Chapter 313. Safety precautions for Handling Electrolytes are covered in paragraphs 19 thru 27 of this Annex.

BATTERIES AND ELECTROLYTES

GENERAL

12. Because the performance of batteries is severely degraded at cold temperatures, ship' s personnel who use battery-powered equipments are more likely to become involved with the handling of batteries during a cold weather cruise than under normal conditions. This handling may include recharging batteries, warming up batteries, which have become too cold or replacing batteries, which are no longer serviceable. In recognition of the potential serious safety hazards involved in handling batteries and electrolytes, this section describes some of the safety precautions which should be enforced at all times. Emphasis is given to considerations, which are especially important under cold weather operating conditions. These and other precautions are described in greater detail in NSTM, Chapter 313.

RECHARGEABLE BATTERIES

13. The most common storage battery used aboard ship is the lead-acid type, which contains an electrolyte solution of sulfuric acid and distilled water. Sulfuric acid is very dangerous to personnel and highly corrosive to equipment or materials.

14. Another type of storage battery, which will be encountered aboard ship is the alkaline type battery containing nickel-cadmium and an electrolyte solution of potassium hydroxide. This electrolyte is also dangerous to personnel and is corrosive to many materials including aluminum and glass.

HYDROGEN HAZARDS

15. **Sparks and Flames**. Both hydrogen and oxygen gas are given off from a storage battery, especially during recharging. Because hydrogen mixed with oxygen or air is very explosive, sparks, smoking or flames of any kind must never be allowed in the vicinity of any rechargeable battery.

16. **Battery Compartment Ventilation**. Extra care is necessary after opening a battery compartment, which has been sealed. Because hydrogen is colorless, odorless and tasteless, such compartments should always be thoroughly ventilated before they are entered. To avoid the possibility of an

explosion, no light switches should be turned on and no electrical connections should be made or broken in the compartment until it has been well ventilated. When preparing to recharge a battery located in a battery compartment, verify that the ventilating system is operating properly before starting the charge. Stop the charge if the ventilation is interrupted.

17. **Charging Rate**. Charge a battery only at the rates given on its nameplate. Reduce the charging rate if the battery electrolyte begins to evolve bubbles of hydrogen and oxygen or if the battery temperature reaches 35°C. Stop charging if the battery temperature approaches the upper limit of 52°C.

18. **Sparks**. To prevent dangerous sparks, ensure that no current is flowing into or out of the battery before disconnecting or connecting battery terminals. When batteries are used with one terminal grounded, the grounded terminal should be disconnected first when removing the battery and connected last when replacing the battery. Verify that all terminal connections are tight to preclude sparks due to loose connections. Use only tools with insulated handles to prevent short-circuiting the battery terminals.

HANDLING ELECTROLYTES

19. **Protective Equipment**. Personnel engaged in handling any electrolyte (or cleaning up a spill) should wear rubber aprons, rubber boots, rubber gloves and goggles or a full face shield so that the electrolyte cannot come in contact with clothing or skin.

20. **Treatment of Electrolyte Burns**. Should acid or electrolyte come in contact with the skin, immediately wash the affected area freely with a large quantity of freshwater for about 15 minutes.

21. Should acid or electrolyte come in contact with the eyes, flush with freshwater for a minimum of 15 minutes ensuring that both upper and lower lids are pulled sufficiently to allow water to flush under them.

22. In either case, the medical department must be notified of the accident as soon as possible and must be requested to come to the site. If the medical department cannot be notified, wash or flush with water for 15 minutes before transporting victim to sickbay.

23. In an extreme emergency, where freshwater is not available, seawater may be used, but only as a last resort.

24. Clothing that may have been splattered with electrolyte should be promptly removed. Skin areas touched by electrolyte beneath contaminated clothing, should be promptly treated by flushing with water as described above.

25. **Replacing Electrolyte**. Nothing but distilled water should be added to a battery except when it is necessary to replace spilled electrolyte. When replacing spilled electrolyte, use only premixed electrolyte, sulfuric acid of specific gravity greater than 1.350 should not be added to a battery.

26. **Concentrated Sulfuric Acid**. Only premixed electrolyte is to be used or stored aboard ship. The use and storage of concentrated acid for the purpose of preparing electrolyte or for adjustment of specific gravity are authorized only for shore activities or ships designated as IMAs. Two of the most important precautions to be followed in handling concentrated sulfuric acid, especially in cold weather are:

a. In making electrolyte, always pour acid slowly into water and never water into acid. The addition of even a small quantity of water to a container of strong sulfuric acid may cause an explosion due to the sudden evolution of heat.

b. Containers of concentrated sulfuric acid must be stored in a place where freezing cannot occur. Under certain conditions, concentrated acid can freeze at temperatures as high as 4°C. Freezing can cause the container to break with consequent grave danger of serious acid burns to personnel.

27. **Prevention of Battery Damage**. Precautions to prevent battery damage also serve to protect the personnel handling the batteries. The following are precautions which should be followed to protect batteries from damage caused by cold weather and related conditions:

a. **Discharged Batteries**. The sulfuric acid electrolyte in a discharged battery can freeze at -15°C whereas, in a fully charged battery, it will remain liquid down to-51°C or below. Freezing may damage the battery internally and/or crack the case causing a hazardous spillage of electrolyte. All batteries exposed to cold weather conditions should be kept fully charged.

b. **Adding Water**. When distilled water is added to a battery to replace that lost during normal operation, the water should be added just before the battery is placed on charge. The water remains on top of the electrolyte until mixed with it by charging. In cold weather, the unmixed water may freeze, causing the battery case to crack and leak electrolyte.

c. **Battery Heaters**. Equipment which may be installed to warm batteries, which are exposed to cold weather should be controlled to keep the battery compartment temperature below 35°C and the battery below 52°C or damage to the battery may occur.

OTHER BATTERY HAZARDS

28. **Gasoline Fumes**. Batteries used for engine starting are frequently located near the engine itself. Care should be taken to avoid sparks when removing or replacing batteries located in compartments, which may contain gasoline fumes.

29. **Salt-water**. Care should be taken not to allow salt-water to splash or leak onto an acid battery because salt-water entering a battery cell will produce chlorine gas which is extremely toxic.

30. Dry Batteries. The following safety precautions should be observed for dry-cell type batteries:

a. **Hydrogen Hazards**. Never continue to use a multi-cell dry battery after its closed circuit voltage has dropped below a value equal to 0.9 volt per cell. Discharging a battery beyond this point will force current through some cells, which may be completely discharged. This will result in the generation of hydrogen and oxygen gases caused by the electrolysis of electrolyte. When this happens, there is danger of a hydrogen explosion and possible injury to personnel and damage to equipment.

b. **Shock Hazards**. Some ships have high voltage dry batteries, like the 300 volt B section of the Navy type 19026 pack battery. They are capable of imparting a very serious, if not fatal, shock to anyone coming in contact with their terminals. When disconnecting them, the current flow should be stopped before disconnecting the plug. It is possible for sufficient gaseous hydrogen to accumulate in this battery to produce a serious explosion if ignited (by the spark caused by pulling the plug while the current is flowing).

c. **Short-Circuits**. In order to prevent a short circuit, wire leads should be kept insulated when the battery is not connected to apparatus. Short circuits may result in sufficient heat to cause a fire. In addition, a discharge caused by a short circuit generally causes the cells to burst, spilling corrosive electrolyte, which can damage equipment and cause injury.

d. **Mercury Cell Batteries**. These batteries may explode if improperly used. Never discharge a mercury cell battery after the battery fails to operate the equipment or the voltage falls below 0.9 volt per cell. Do not leave the battery switch on when the equipment is not in use or after the battery fails to operate the equipment. Never impose a dead short-circuit on a mercury cell or allow it to become over-heated. A temperature of about 204øC will cause such a cell to explode. Discard exhausted mercury cell batteries as soon as possible. Dead single and multi-cell batteries with steel jackets should have holes punched in the jackets before being discarded to release any gas which might have formed. Follow proper disposal procedures.

EQUIPMENT SAFETY

GENERAL

31. Safe handling of equipment cannot be over-emphasized, particularly in a cold weather environment. The dangers associated with operating much equipment during routine evolutions in a moderate climate are sometimes formidable. In a cold, harsh climate there is no such thing as a routine evolution. Evolutions typically take 2-3 times the normal period to perform. Every operation requires effective planning and extra attention to safety for successful completion.

32. This section addresses some particular safety concerns when operating equipment in cold weather. The purpose is to encourage a thoughtful, safety-conscious approach to hazards involved.

EQUIPMENT HANDLING WITH WEATHER CLOTHING

33. Equipment handling may be difficult while wearing cold weather clothing because maneuverability and dexterity will be reduced as the thickness of clothing increases. Mittens and gloves make it more difficult to grasp some objects, such as wrenches and screwdrivers. It will be nearly impossible, for example to fine-tune electronic equipment with small potentiometer knobs while wearing large gloves. The following safety precautions should be observed while wearing cold weather clothing.

a. Be extremely careful while handling heavy equipment. Ensure properly fitted gloves of suitable warmth are worn. Leather gloves with liners are good for handling equipment and lines. It is also important to keep hands dry to prevent numbness. Carry extra liners to replace wet ones.

b. It is permissible to remove hand protection for short periods of time if necessary to perform particular tasks. Precautions should be taken not to touch any cold metal surfaces or to get hands wet. Put gloves back on between evolutions to maintain warmth. Alternatives to removing gloves include modifying gloves or mittens to suit a particular task, such as cutting a trigger finger hole, and wearing light glove liners to improve dexterity without exposing bare hands.

c. Hoods are very effective for keeping the head warm but they can also hinder vision and head movement. Consider wearing wool caps and scarves in place of hoods when unobstructed view and movement are needed.

Annex E

Arctic Ocean Plotting Chart